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INDIANA UNIVERSITY STUDIES

22. THE FLOOD OF 1913 IN THE LOWER WHITE RIVER REGION OF INDIANA. By HAL P. BYBEE A.M., AND CLYDE A. MALOTT, A.B.

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The 'University Studies' constitute a sub-series of the Indiana University Bulletin *in which from time to time are published some of the contributions to knowledge made by instructors and advanced students of the University. At present not more than two or three such numbers are issued a year. The 'Studies' are continuously paged and numbered, and, as needed, a title-page and table of contents will be issued, for binding them up in volumes.*

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No. 22 BLOOMINGTON, INDIANA

CORRECTIONS

Page 107, table of contents, "Cause of Floods in the Ohio Valley," for "135" read "134." In the same way for each succeeding topic to "Summary of Damage to Soil" the pages should read "137," ,"138", "140", "140", "142", "142" "144", "144" and "145" respectively.

Page 111, 8th line from the bottom, for "4" read "5".

Page 123, end of first paragraph, add "page 168".

Page 142, 14th line from the bottom, for "15" read "14".

Page 145, 1st line, for "3" read "4".

Opposite page 168, add "chart No. 6" to the chart.

Page 173, in last paragraph, after "C" in the 12th line from the bottom add "page 115."

Opposite page 174, on the chart, for "7" read "8".

Opposite page 176, on the chart, for "8" read "9" and for "7" read "8".

Page 178, 16th line from bottom for "2" read "3".

Page 179, 1st and 22nd lines for "2" read "3".

Page 180, last line, for "3" read "4".

Page 181, 2nd line from the bottom, for "4" read "5."

Page 182, 3d and 6th lines from the bottom, for "5" read "6".

Page 184, last line, for "Martin" read "Morgan."

Page 189, last line, for "3" read "4".

Page 192, cancel "(See figure 47.)"

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Prefatory Note

It was realized that a thorough study of the flood of March, 1913, was necessary in order to determine the actual conditions and the consequences of it. The matter was called to the attention of the President of the University and an appropriation of $150.00 was made for the purpose, as a part of the Public Service Work of the institution.

Mr. Hal P. Bybee was placed in charge of a party consisting of Mr. Clyde A. Malott and Mr. Thomas F. Jackson. Mr. Jackson left the party at Worthington, on account of illness, and Mr. W. R. Allen took his place. On account of their accessibility, the two forks of White River were chosen for study. As soon as physical conditions would permit, the party took the field and the work was carried on under the most trying conditions.

The report which follows is the joint collaboration of Mr. Bybee and Mr. Malott, and forms the first accurate record of a great flood in the area studied, together with a discussion of the actual conditions found, and the precautionary measures that may be taken.

J. W. BEEDE,
Associate Professor of Geology.

Accepted for publication in the INDIANA UNIVERSITY STUDIES.
SAMUEL B. HARDING,
WILL D. HOWE,
ARTHUR L. FOLEY,
Committee.

Table of Contents

The Flood of 1913 in the Lower White River Region of Indiana

By Hal P. Bybee, A.M., and Clyde A. Malott, A.B.

PART I. INTRODUCTION

Acknowledgements

The recent March flood in the Ohio Valley brought such disaster and ruin upon the people within its scope that it will be long remembered, and will be used as a guage for floods of the future, whether of this particular region or elsewhere in the Mississippi Valley. Realizing this, the Department of Geology of Indiana University sent out an expedition as a part of the Public Service work of the University, to study the effects of the flood along the West Fork of White River. The field work was done mainly by the writers, each of whom traversed a bank of the stream, carefully noting the conditions under which any damage was done. Much aid was given by Mr. Thomas F. Jackson, a graduate student in the Department of Geology, who took charge of the boat and noted changes that took place in inaccessible places. To Mr. Jackson, credit is due for preparing the photographs. The writers are indebted to Dr. J. W. Beede for his valuable suggestions and general supervision of the work. Dr. E. R. Cumings has given much valuable criticism and has aided the writers greatly by his suggestions. The photographs of the region below the junction of the two White Rivers were contributed by Mr. Harry W. Morrison, county surveyor and engineer of Gibson County.

It was almost three weeks after the crest of the flood had passed before the flood plain was dry enough to permit the work to be undertaken. On April 19, the party started at Waverly, near where the river enters Morgan County. Some three weeks were required to traverse the river valley through Morgan, Owen, Greene, and between Knox and Daviess counties, to the junction with the East Fork of the White River. At Worthington, in Greene County, Mr. Jackson was succeeded by Mr. W. Raymond Allen, a graduate student of the Department of Zoölogy of Indiana University.

After the party had traversed the West Fork from Waverly to the junction with the East Fork, a distance of about 200 miles by the river, it was found that the funds which were furnished for the expedition by the University were sufficient to cover the expenses of an investigation of a considerable portion of the East Fork of White River. Accordingly, the equipment was shipped to Brownstown, near the middle of Jackson County. Two weeks were consumed in the investigation of the East Fork from Brownstown through one-half of Jackson, Lawrence, and part of Martin Counties to Shoals, making a distance of about 110 miles along the East Fork. Thus, five weeks were spent on the expedition, and about 310 miles of river bottom traversed.

Since a flood of the magnitude of the recent one does not occur more than once or twice in a generation, it was not known just what was to be found or what were the most important phases of the situation. In a very short time, however, the following things revealed their need of consideration:

1. Effect of bridges, both highway and railroad, upon the height of the water.
2. Railroad grades and public road grades.
3. Bank cutting, amount, causes and prevention.
4. Deposits of sand, silt and gravel.
5. Removal of the top soil.
6. Cutting of holes, causes, and prevention.
7. Effects of meanders.
8. Levees, their good points and their bad points.
9. Effect on the future crops, and the destruction of wheat and corn.
10. Damage to cities, towns, and villages, and to farm improvements.

Valuable aid was given by the farmers along the river bottom in the consideration of the above items. As far as possible each farmer was questioned about the March flood and his opinion procured as to damage. Since soil was the main physical loss to the valley land, farmers were questioned on every possible occasion as to their ideas of the damage to future crops on account of the removal of the top soil. The effect of grades, both of public roads and railroads, was discussed with those affected.

Lack of Good Base Maps

One of the most serious handicaps that was encountered in doing the work in a first-class manner was the lack of a good base map with which to work. The soil and county maps that were available were far from being accurate in geographic detail; and thus it was almost impossible to note the lesser changes made by the high water. It is the little changes that are taking place from year to year, that in the end make the greatest change, or lead up to some marked change in the course of a stream. There are several places where as much as three acres are lost each year. It was not uncommon for as much as forty acres to have been lost in the short time of ten years. This is the case at the first bend in the river after it turns south at Spencer. Again in twenty-seven years, twenty acres have been lost from the John Duke farm, between Worthington and Bloomfield. These changes and hundreds of others are taking place all the time and in a few years make a considerable change in river channel. Without the aid of topographic maps it is impossible to note these changes.

If a complete topographic map of the White River bottom were available, a study of the situation could be made and the advisability of a system of levees for any part of the river bottom could be worked out. As it is, nothing but an expensive survey of the entire bottom will show the advisability of such a system. When such a survey was finished, there would be nothing that could be used later for any other specific purpose; while the same amount of money with a little more added to it would make a permanent topographic map that could be used in making a complete study of the entire situation. With such a map having a ten foot contour interval, the geology and physical features of the river valley could be worked out. The advisability of making cut-offs, thus shortening the stream, and even the approximate cost of such work could then be determined. For instance, at Bloomfield, just below the Illinois Central Railroad, the river makes a long loop to the south, as seen in Chart No. 4. At the southern end of the loop a new channel less than a third of a mile in length would shorten the course of the river over a mile. With a good base map to work from, the position of the proposed cut-off could be determined at a place where there would be the least possible bank cutting and the most land reclaimed by such a cut-off. A close study of a topographic map would furnish an engineering corps with sufficient data to work from. That is, they would

know what they were to find and the easiest and least expensive manner of procedure.

The Mississippi River Commission started its work by having made a large scale contour map of the entire lower course of the Mississippi River. With this base map to work from, other surveys have been made, and the entire lower course of the Mississippi River has been brought under almost complete control. Not only could the topographic maps be used in the study of the flood situation, but they could be used in the study of the improvement of the public roads in the unglaciated part of the State. By looking at the contour map of the Bloomington Quadrangle, it will be seen that the roads are built on the section lines, in a good many instances making the road so hilly as to prevent the marketing of the crops, and making heavy hauling almost impossible. These roads could be built around hills of excessive steepness and height, in many cases, where they are now built on the section line directly over the hill. Also the location of road metal quarries could be made in the best possible location with respect to applying the metal to the road.

The possibilities of storing the excess flood waters in the lake region of the northern part of the State for irrigation and power purposes could be worked out in a definite manner by the aid of adequate topographic base maps.

It would be well to place topographic maps in the public schools, for social as well as physical problems may be studied by their use. An example of the social problems that may be studied by the aid of the contour map is found in the following question: 'Can the people that live on the part of the river valley that is frequently overflowed move to higher locations?' Or, 'Are they a poorer class of people that are not financially able to make such a move? Are they renters or do they own their own homes? Could these low lying districts be turned into public parks which would not be seriously damaged by the overflow of the stream?'

The estimated damage to soil on the part of the White River bottom traversed was something near $250,000. The cost of making a map of a fifteen minute quadrangle varies from $1,350 to $5,750, according to the nature of the topography, or from $6 to $25 per square mile. At the lesser figure, the entire drainage area of both forks of White River could be mapped for $75,000. Putting the cost at $2,500 for each quadrangle, the entire drainage of both forks of White River could be mapped for $132,000, or about one-half the estimated loss to soil in the recent flood. For the estimated loss of soil, the whole State could be mapped. About fifteen fifteen-minute quadrangles would cover the greater part of the valley land on both forks of White River and would cost less than one-third of the estimated damage to soil in the recent flood. These figures are possibly too high, for the relief in Indiana is not very pronounced, especially in the glaciated part of the State.

General Laws of a Stream

In the work of water, as it is emphasized along any stream from a mere rivulet to a great river, a few principal laws come under consideration which are applied to any particular stream. Since these laws are fundamental, a few pages are here devoted to a consideration of them.

'Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportional to its size, and all of them together forming a system of valleys communicating with one another, and having such a nice adjustment to their declivities that none of them join the principal valley either at too high or too low a level, a circumstance which would be infinitely improbable if each of these valleys were not the work of the stream flowing in them.' (John Playfair, 'Huttonian Theory of the Earth.')

Streams are one of the most important agencies that give form and expression to the surface of the earth; they are the principal factors in fashioning the details of the various topographic forms that strike the eye of the every-day observer. Streams cut into the plains, making valleys and hills suited to the size of the streams and proportioned to the general elevation of the former plain above the mouths of the main streams.

Every one is aware that streams carry sediment, and especially after rains during high water. When one considers that streams, ever and ever, are carrying sediment, he soon is able to grasp the idea how streams are able to carve the surface of the earth as they do. During each high water millions and millions of tons of sediment are carried to the ocean. Nearly every one has noticed that during the short summer shower a considerable gully may be made on a hill side, that started from a little rill in the mark of a harrow tooth. The soil thus removed, however, may be at the foot of the same hill. In fact the soil from the source of a stream may make many stops before it finally reaches the ocean.

It may lay in the form of alluvial material for centuries before it is removed to its final resting place in the ocean. A summary of the denudational processes in the United States is given in 'Water Supply Paper No. 234,' by Dole and Stabler. The last paragraph is as follows:

> The estimates reveal that the surface of the United States is being removed at the rate of thirteen ten-thousandths of an inch per year, or one inch in 760 years. Though this amount seems trivial, when spread over the surface of the country, it becomes stupendous when considered as a whole, for over 270,000,000 tons of dissolved matter and 513,000,000 tons of suspended matter are transported to tide water every year by the rivers of the United States. This total of 783,000,000 tons represents more than 350,000,000 cubic yards of rock substance, or 610,000,000 cubic yards of surface soil. If this erosive action had been concentrated upon the Isthmus of Panama at the time of American occupation, it would have excavated the prism for an eighty-five foot sea level canal in about seventy-three days.

It has been shown by Humphreys and Abbott that the Mississippi River alone transports enough sediment to tide-water in one year to build up a tract of swamp land 268 square miles in area one foot in depth. There has been no consistent effort toward using this enormous quantity of sediment that the rivers of the United States carry to the ocean, and as a result all of this good soil is lost. In the case of the Mississippi River, the sediment might be used to build up some of the vast areas of swamp land along its lower course, so that something besides malaria might be produced where the swamps now are.

The manner in which material is acquired by running water, the way in which it is carried, the effect it has on the bottom and sides of a stream, and how it modifies the flood plain in times of flood can be ascertained by the careful study of a single stream. We think, ordinarily, that the function of a stream is to carry away the stupendous amount of flood water and the general run-off, while in reality its purpose is that of leveling. Salisbury says the purpose of a stream is to carry the lithosphere into the hydrosphere. The term 'leveling' may seem contradictory to the previous statement that streams make hills and valleys; but leveling is their function in that they reduce, very slowly to be sure, the land to sea level, or approaching it. They etch their way into the plains and cut them into hills and valleys and these hills are in turn worn to a base level. No one person can live long enough to see the life history of any one stream completed, but the physiographer sees many examples of streams representing all stages between youth and old age. He may see stages in which the stream has all of its

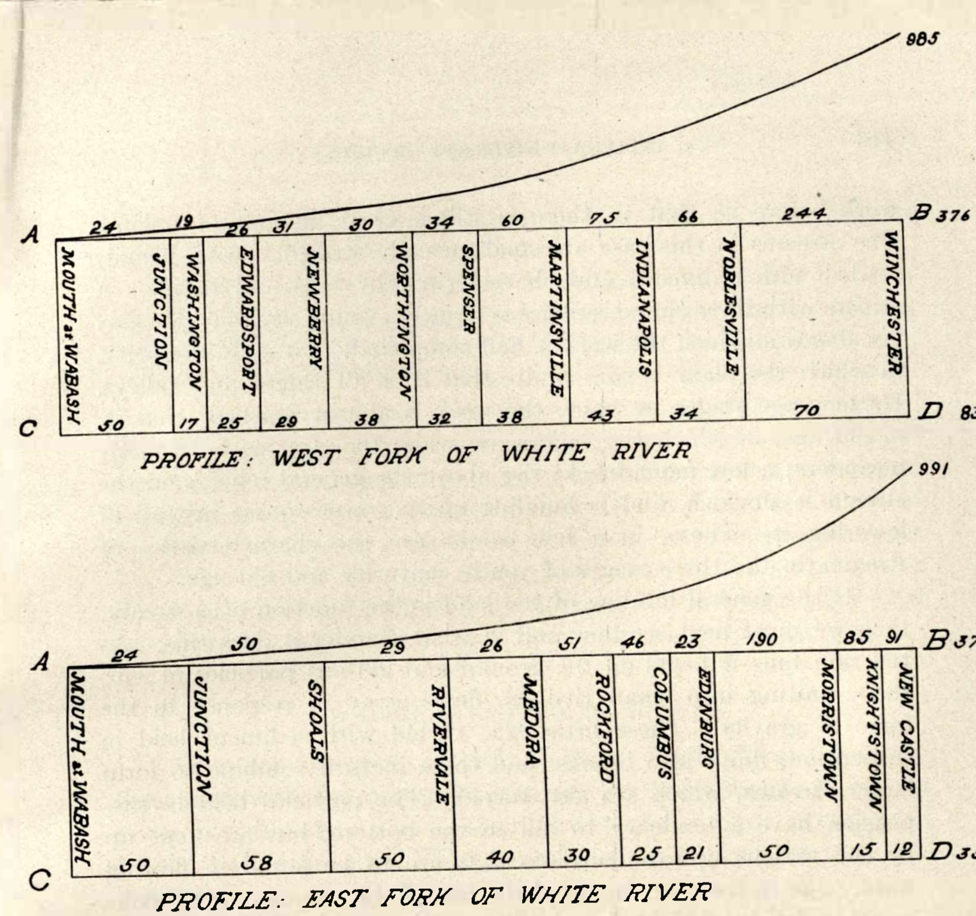


DIAGRAM No. 1.

Figures along the tops of the two diagrams, A to B, are fall in river from one town to the next one mentioned.

Figures along the bottoms of diagrams, C to D, represent distance in miles from one town to the next one mentioned.

Figures at right end of curve show elevation of river at Winchester and New Castle above sea level.

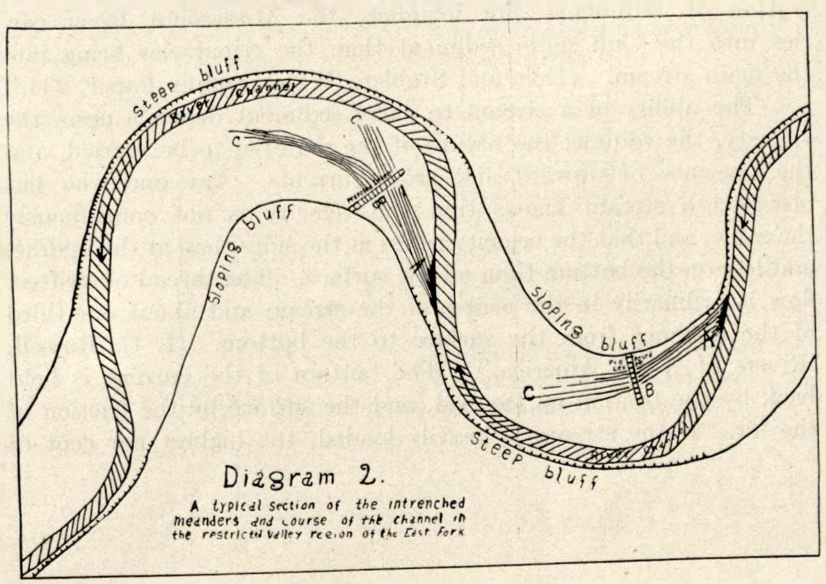


Diagram 2.

A typical section of the intrenched meanders and course of the channel in the restricted valley region of the East Fork

work before it; that is, there is still a great amount of upland. The streams in this case are small, usually straight, swift, heavily loaded with sediment, and characterized by falls and rapids. A stream with these characteristics is termed a young stream. He may see stages in which the work is half completed; that is, in maturity, in which the plain is so cut up that it is all ridges and valleys. He may see stages in which the work is almost finished; that is, in old age, in which the valleys are wide; the streams have many meanders; a few monadnocks rise above the general relief; and the stream is sluggish, and is building up its lower course instead of lowering it. These, in a few words, are the charactertistics of streams in the three stages of youth, maturity and old age.

If the general leveling of the land is the function of a stream, then we must next see how and in what manner it does this. As the rain falls it beats on the ground and gathers particles of soil; then, uniting into small rivulets, flows away in response to the force of gravity. These little rills, turbid with sediment held in suspension, unite into brooks, and these in turn combine to form larger streams, which are also turbid. The particles held in suspension have a tendency to fall to the bottom, but are kept up by the various upward currents that are to be found in flowing water, due to the unevenness of the bed of the streams, or to rocks or other debris on the bottom. The sediment may rest on the bottom for a time, but it will be gathered up and carried on down stream and will finally arrive at its resting place in the ocean.

Not only is the sediment gathered up by the little rills, but the main stream is constantly widening and often deepening its channel. This process also furnishes another source for the derivation of sediment. For instance, the Mississippi River carries into the Gulf more sediment than the tributaries bring into the main stream. (Dole and Stabler, 'Water Supply Paper, 234.')

The ability of a stream to carry sediment depends upon the velocity, the volume, the nature of the material to be carried, and the presence of upward and cross currents. Any one who has observed a stream knows that the velocity is not continuously the same, and that the velocity is less at the sides than at the middle, and less on the bottom than on the surface. The thread of swiftest flow is ordinarily in the center of the stream and about one-third of the distance from the surface to the bottom. (I. C. Russell, 'Rivers of North America.') The bottom of the current is held back by the friction on the bed, and the surface by the friction of the air. If the stream is heavily loaded, the highest per cent of

sediment is found where the current is less—that is, near the bottom, surface, and sides of the stream.

Another class of debris that is carried by a stream in times of flood includes tree trunks, logs, rails, bridge planks, boards, telephone poles, and everything that will float or that can be held up by the current. These things cause much damage in that they have a tendency to form a dam whenever they may become lodged. In this way many bridges are washed away. The road west of Martinsville was damaged to a great extent by the cross currents set up by the debris catching on the wire fence on the north side of the road and forming a dam. L. C. Glenn, in 'Professional Paper No. 72, U. S. G. S,' cites many illustrations of mills and power plants having been destroyed by floating debris becoming lodged against them and finally forcing them from their foundations.

Geologic Structure of Indiana

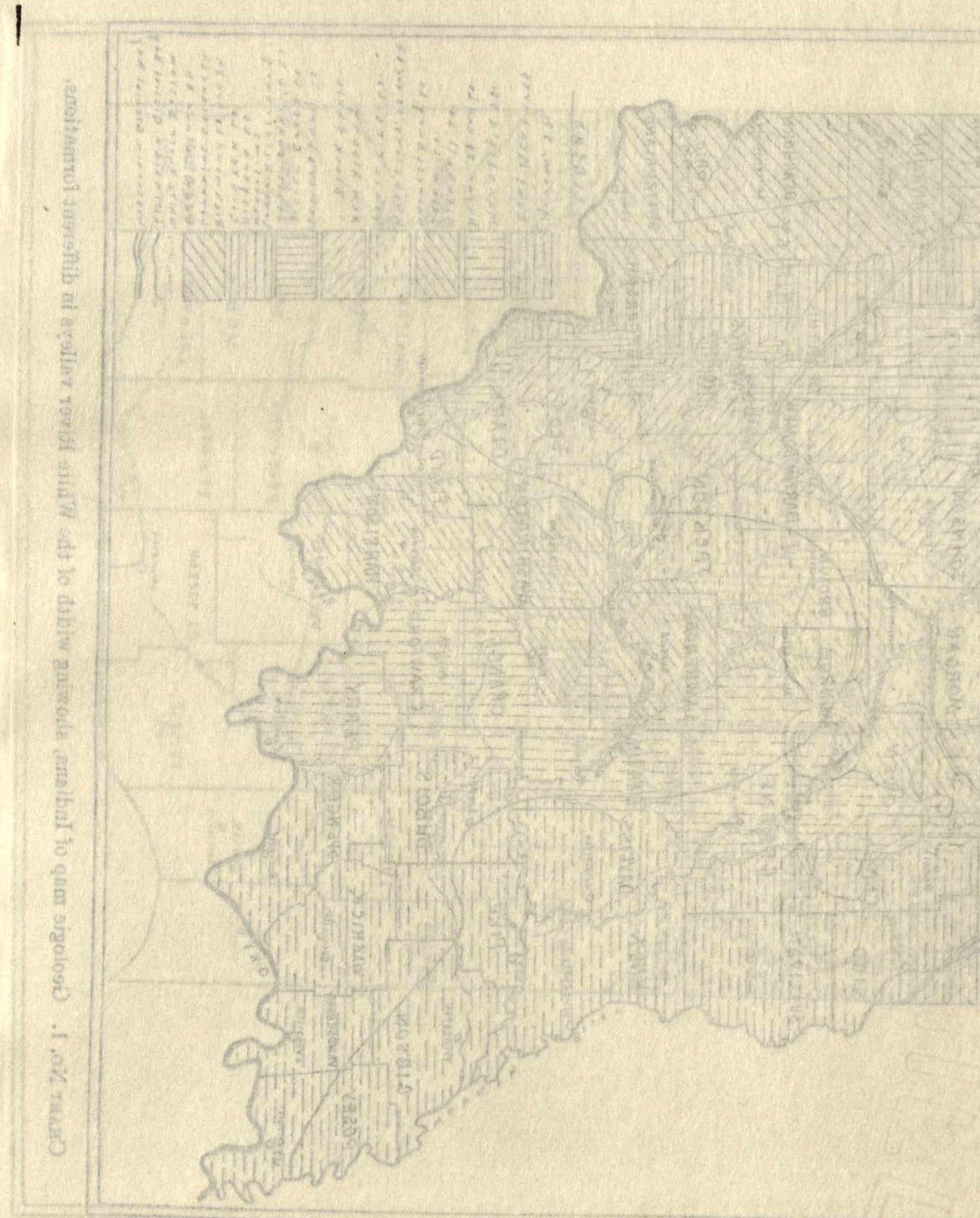
Since the drainage of both forks of White River is closely associated with the geological structure, a brief discussion will be given at this time. The geologic history of the State is embraced by the Paleozoic times. The geological scale for Indiana is as follows:

Paleozoic	Pennsylvanian	Merom sandstone Coal measures Mansfield sandstone.
	Mississippian	Chester sandstone and limestone Mitchell limestone Oolitic limestone (Salem) Harrodsburg limestone Knobstone sandstone and shales Goniatite limestone.
	Devonian	New Albany black shale Sellersburg limestone Silver Creek limestone Jeffersonville limestone
	Silurian	Waterline Niagara limestone Clinton limestone.
	Ordovician	Richmond limestone and shales Lorraine limestone and shales Eden shales and limestones Trenton limestone.

The geologic history of Indiana begins with an old sea which gradually retreated to the southwest as the region to the northeast was raised. The general dip of the rocks is to the southwest, at the rate of twenty to thirty feet to the mile. In some places the dip is much more, at times, being as much as a hundred feet to the mile. Beginning with the Ordovician formations which are the oldest rocks found in Indiana, the other formations are exposed as one goes from east to west across the State, until the Merom sandstone is reached at the extreme western part of the State. In each case, the older passes under the younger, and each is exposed at the surface for a distance dependent upon the thickness of the formation and the amount of stream erosion.

Ordovician. The Ordovician rocks are the oldest rocks exposed in Indiana. They consist of a series of hardened clays and thin bedded limestones, commonly designated as the Cincinnati group. This region includes a strip from fifteen to twenty-five miles in width extending from the Ohio River northward to the northern part of Wayne County. The entire territory is drained by Whitewater River, and other streams that flow into the Ohio River. Since shales are easily eroded, the relief is rather pronounced, being as much as four hundred feet. The limestones of the region are very thin, rarely more than a few inches in thickness, thus affording very little protection to the shales. The region in general is one of the physiographic divisions of the State and may be called the Eastern Highland, the elevation above the sea being from 700 to 1,200 feet.

Silurian. The Clinton and the Niagara limestones of Silurian age succeed the Ordovician rocks. They are the surface rocks along the Ohio River, extending in a narrow strip northward through the eastern part of Clark County, the middle of Jefferson County, the eastern part of Jennings County, thence with the western limit near Greensburg and Rushville, northwest past Noblesville, as indicated on Chart No. 1. From Rushville south the outcrop will average fifteen miles in width, except at the extreme southern part. The Clinton limestone, which is basal Silurian in Indiana, is a rather thin bed, varying from a few inches to about seven feet in thickness. The Niagara group, which overlies the Clinton limestone, is composed of several divisions of limestone and shales, aggregating in all about one hundred and twenty-five feet, in the southern part of the State. To the north where the Niagara passes under the glacial drift, it reaches a thickness of four hundred feet. The topography of the Niagara limestone outcrop is rather



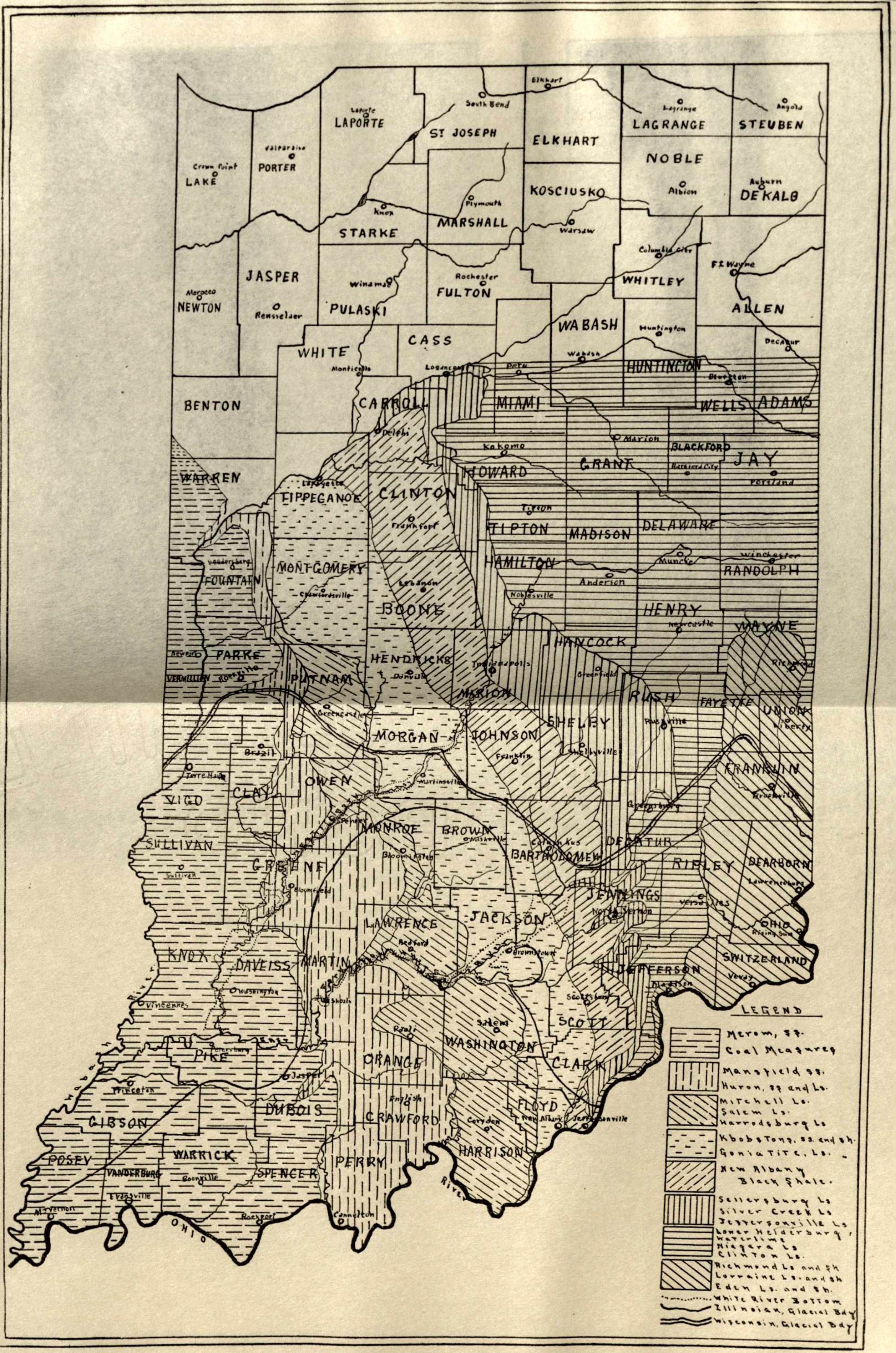


CHART No. 1. Geologic map of Indiana, showing width of the White River valleys in different formations.

FIG. 3. Hole where a haystack had been. In the background, a crew replacing the grade that was washed out on the east side of B. & O. bridge across White River, three and a half miles south of Bedford.

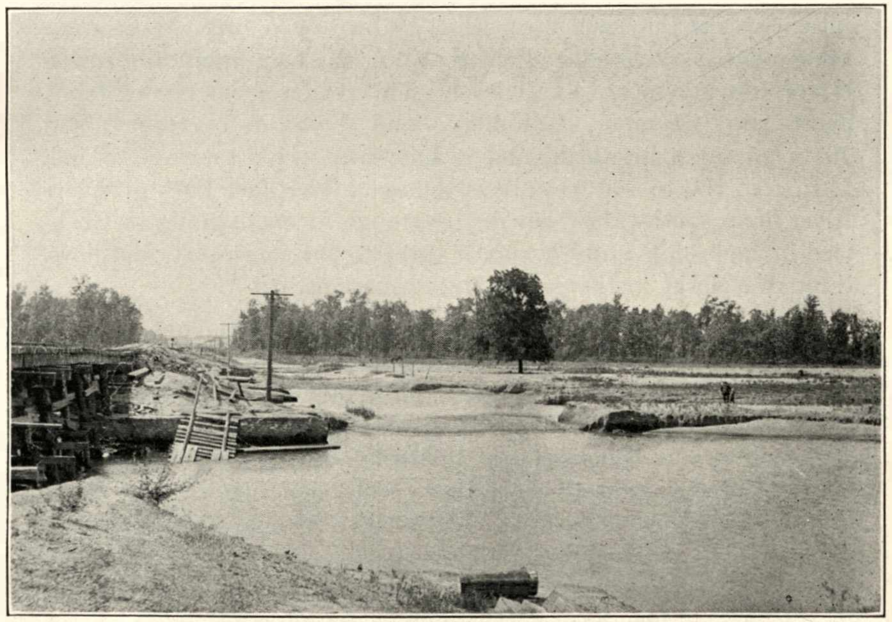


FIG. 4. A hole washed out at Summers ditch crossing, west side. Size of hole, 100 feet wide by 300 feet long by 30 feet deep.

rough, the steep slopes being the result of the predominating limestones, and is somewhat in contrast to the rounded hills of the Eastern Highland of southeastern Indiana. The general slope is to the west. The eastern rim of the Clinton and the Niagara is the dividing line between the White River and Whitewater River systems. The streams flow southwest down the dip of the rocks and the Niagara is exposed in the bed of the streams for several miles to the west of the general outcrop.

Devonian. The Devonian rocks succeed the Silurian, and may be grouped into two main divisions, the lower being limestones and the upper soft shales. The most important limestone is the Corniferious, or Jeffersonville, which is a rather hard bluish gray limestone, the combined strata averaging about sixty-five feet in thickness. To the north it seems to be partly replaced by the Geneva, a buff or brownish colored magnesian limestone. Above the Jeffersonville limestone, are two thin beds of limestone known as the Silver Creek and the Sellersburg. These outcrop in the extreme northern part of the region. On top of these limestones occur the New Albany Black Shales, which will average 125 feet in thickness. These shales are sulphurous and contain so much bitumen that they will burn when thrown on a fire. Weathering takes place very rapidly in these shales and as a result the region is worn down almost to base level. This region about New Albany, Scottsburg, Seymour, Columbus, and Franklin averages about 10 to 15 miles in width, and is known as the Eastern Lowland. It is from 500 to 700 feet above the sea. The East Fork of White River flows southward through this trough for many miles to Rockford in Jackson County, where it turns to the southwest, and flows through a gorge in the succeeding formations.

Mississippian. The Mississippian strata, in Indiana, occupy the middle portion of the southern half of the State, and next to the Pennsylvanian, are the most important rocks in the State. The Mississippian in Indiana is divided into six divisions, which aggregate over a thousand feet in thickness. These divisions will be treated in the order in which they occur, beginning with the Goniatite limestone, which is the oldest. The Goniatite limestone is unimportant, but is remarkable in its consistency in underlying the whole Mississippian system. It is generally less than six feet in thickness. The Knobstone group is composed of shale at the bottom, while near the middle are massive dark blue calcareous and clayey sandstones, and near the top is a light brownish sandstone intercalated with shaley layers. The Knobstone is between 400 and 600 feet in thickness. The area of outcrop is from twenty-five to thirty miles in width and extends from the Ohio River northward through Floyd County, western Clark, eastern Washington, western Scott, nearly the whole of Jackson, Brown, Morgan, Hendricks, and Montgomery Counties, passing under the glacial drift in Benton County. The topography of this region is the most rugged of any in the State. The Knobstone rocks absorb water readily, but being impervious, transmit it very poorly, so that these rocks are readily shattered by freezing and thawing. The region is weathered and eroded into steep-sided valleys, the bottoms of which are from 200 to 400 feet below the general level of the land. The topography of Brown County is a good example of these steep-sided valleys. Since the elevation of the region is from 700 to 1,100 feet above the sea, it is known as the Central Highland. The courses of both forks of White River are to the southwest directly across the Knobstone region. The valleys are from two to five miles in width and are bordered on either side by abrupt, bluish bluffs, ranging from 150 to 250 feet in height. Typical bluffs of this kind are to be found on the West Fork above Martinsville and on the East Fork at Brownstown and Sparksville.

The Harrodsburg limestone which overlies the Knobstone, is a coarsely crystalline, fossiliferous, hard, blue stone from 35 to 100 feet in thickness. Its outcrop is between a quarter of a mile and three miles in width. The topography is very similar to that of the succeeding formations.

The Salem limestone overlies the Harrodsburg limestone. It is a massive, oolitic, buff to bluish, fossiliferous limestone, known over the United States as one of the best building stones. The softness of the freshly quarried rock makes it very easily worked, and upon exposure to the air it gets hard and durable. The thickness of the Oolitic limestone varies from a few feet up to 90 feet.

The Mitchell limestone is a hard, fine grained fossiliferous, blue stone, having a thickness ranging from a few feet up to, possibly, 250 feet. This limestone is easily soluble and is pitted over its entire outcrop with sinks. The region of its outcrop is largely drained by underground channels. It is in this formation that some of the largest caves of the world are found. Some of the noted caves found in the Mitchell limestone are Mammoth Cave of Kentucky, and Wyandotte and Marengo Caves of Crawford County, Indiana. Lost River in Orange County is a typical underground stream for thirteen miles of its length. Green River, Kentucky, drains Mam-

moth Cave and is another example of the solubility of the Mitchell limestone. The Harrodsburg, Oolitic or Salem, and the Mitchell limestones are shown in Chart No. 1 as one formation. Through this limestone region both forks of White River narrow down to about a quarter of a mile in width. This narrowing of the valley in passing from the region of soft shales and sandstones to the hard limestones had remarkable effect on the flood conditions, as will be mentioned in another place.

The last division of the Mississippian is the Chester. This consists of a series of thin limestone, shales and sandstones, aggregating 190 feet in thickness. There are three thin limestones with sandstone and shales between.

Coal Measures. The Mansfield sandstone is a massive, coarse-grained sandstone and is the basal member of the coal measures in this State. On top of the Mansfield Sandstone is a series of shales, sandstones, coal seams, fire clays, and limestones. The shales make up the greater part of the coal measures. The Merom sandstone lies next above the coal measures. Mr. J. F. Newsom in the '26th Annual Report of the State Geologist,' says: 'Lying above the productive coal measures and separated from them by an unconformity is a sandstone with a thickness at Vincennes of from 40 to 50 feet. This sandstone has been known as the Merom sandstone, owing to its good exposures at the town of Merom. In general appearance it resembles the Mansfield sandstone, for which it has sometimes been mistaken. Whether it is of carboniferous, or later, age has not been satisfactorily determined.'

It is interesting to note that the size of the valley depends on the material through which the river flows. Above Gosport, on the West Fork, the river flows through the Knobstone region, which is composed of shales and thin bedded sandstones. These shales are easily eroded and as a result the valley is wide; being one to three miles in width. As the Limestone region is reached below Gosport, the valley narrows to between a quarter and three-quarters of a mile, until it leaves the Mansfield sandstone below Bloomfield, where it again widens even more than above Gosport. The same conditions are present on the East Fork. At Sparksville the wide valley narrows to a mile or less as it leaves the Knobstone region and enters the limestone area, and continues very narrow until it leaves the Mansfield sandstone at Shoals. Thus there is a remarkable constriction in the valleys of both forks where they flow through the limestone rocks and the more resistant Mansfield sandstone. It may be stated that House Rock and Jug Rock,

at Shoals, are in the Mansfield sandstone. As the valley becomes narrow, the depth of the water is increased and the amount of damage per acre is increased. At Romona, on the West Fork, the valley is about a quarter of a mile in width, and as a result the water during the flood was about thirty feet in depth on the valley, and the entire valley was swept clean (Fig. 1).

Drainage Area of White River

Both forks of White River rise near the highest point in the State, which is in Randolph County. This elevation is about 1,285 feet above sea level. The Mississinewa and the Whitewater Rivers also have their sources in this county. The East Fork rises in the very southwest corner of the county.

The West Fork flows in a westerly direction through Muncie, and Anderson, to Noblesville, then almost due south to Indianapolis. From Indianapolis it takes a direct southwesterly course to Petersburg. The West Fork flows through the Wisconsin glacial drift from its source to Martinsville, a distance of 125 miles, and in the Illinois glacial drift from Martinsville to the forks, a distance of 180 miles by the river.

The East Fork flows in a tortuous, winding manner, thus increasing its length and decreasing its fall by numerous meanders. The East Fork flows through the Wisconsin glacial drift from its source to Columbus, about 155 miles. Then in the Illinois drift from Columbus to Brownstown, a distance of 40 miles. From Brownstown it flows through the unglaciated part of the State for about 90 miles, and the last 40 miles are again in the Illinois glacial drift.

The writers have measured the drainage area of White River with a planimeter on a large scale map. ('Geologic Map of Indiana,' compiled by T. C. Hopkins, 1901–1903.) The areas were measured four times, with the following average results:

West Fork of White River	5,340 square miles.
East Fork of White River	5,580 square miles.
White River between the forks and Wabash	175 square miles.
Total drainage area	11,095 square miles.

TABLE No. 1—Profile of the West Fork of White River.[1]

Stations.	Distance Apart.	Distance from Noblesville.	Elevation.	Feet of Fall between Stations.	Fall per mile between Stations, in Feet.
Noblesville	0	0	741	0	0.0
Indianapolis	34	34	675	66	1.9
Martinsville	43	77	600	75	1.7
Spencer	38	115	540	60	1.6
Worthington	32	147	506	34	1.06
Newberry	38	185	476	30	0.8
Edwardsport	29	214	445	31	1.0
Washington	25	239	419	26	1.0
Junction	17	256	400	19	1.10
Mouth	50	306	376	24	0.45

Profile of East Fork.

Stations.	Distance Apart.	Distance from Morristown.	Elevation.	Fall Between Stations.	Fall per Mile Between Stations.
Morristown	0	0	741	0	0.0
Edinburg	50	50	625	116	2.3
Columbus	21	71	602	23	1.1
Rockford	25	96	556	46	1.8
Medora	30	126	505	51	1.7
Riverdale	40	166	479	26	0.65
Shoals	50	216	450	29	0.58
Junction	58	274	400	50	0.86
Mouth	50	324	376	24	0.45

[1] W. M. Tucker, Indiana Department of Geology and Natural Resources, 1910. The last two columns were added by the writers.

A study of the two profile tables shows a noticeably high fall at the source of the two streams, which rapidly decreases until Columbus is reached on the East Fork, and Noblesville on the West Fork. (Diagram No. 1 shows this very well.) The fall above Noblesville is between three and four feet to the mile. On the East Fork

the fall between Rivervale and Medora becomes as low as eight inches to the mile and between Rivervale and Shoals as low as seven inches to the mile. On the West Fork there is only one place where the fall goes below a foot to the mile, and that is between Worthington and Newberry, where the fall is a little less than ten inches to the mile.

Meteorological Conditions

Conditions for March 23–27, inclusive.[2] There is nothing to be found in a study of the weather maps of the period preceding the heavy rains that would indicate such conditions as caused the downpour that followed. The 'low' on Sunday night, March 23, 1913, overlaid southeastern Nebraska. On that day there were heavy rains from central Illinois to Western Ohio, over a strip of country probably 200 miles wide and 500 miles long, the focus of the heavy rains being in northeastern Indiana and northwestern Ohio.

Rain fell uninterruptedly over the above territory, Sunday night March 23. The amount of precipitation, however, was not so great as on the following day. In Illinois, on March 24, rain ceased, but the intensity over southern Indiana and southern Ohio increased and was greater than on the previous day. Here an important thing is to be noted: On March 23, the heaviest rainfall was on the head waters of the Wabash, White River, and the rivers of Ohio that flow into the Ohio River from the north; and on March 24, the heaviest rainfall had shifted to the lower parts of these rivers. This is a reversal of the ordinary conditions; for the ordinary storm moves from the lower part of these streams to the upper portions of their drainage areas, thus giving the water that first falls a chance to run away before the rainfall of the second period reaches it.

Monday night, March 24–25, brought a continuation of the rain over Illinois, Indiana, and northern Ohio. The same belt of heavy rain extended along the lower part of the Great Lakes down the St. Lawrence valley, into northern New England. As on the day before, the area of heaviest precipitation was in central Indiana and in central and northern Ohio during the daylight hours of March 25. It was the rainfall of this day, Tuesday, March 25, with its average of 4.46 inches of rain at sixteen out of the twenty stations in the White River drainage area, that sent the streams of central Indiana on their mission of unprecedented destruction.

[2] *Monthly Weather Review*, March, 1913.

The position of the 'highs' and the 'lows' during the period of March 23–27, is responsible for the continuation of the excessive downpour in the Ohio Valley. As nearly as possible, the following is the succession of events that caused the continuous downpour: In advance of the first storm, that formed on the 22nd and centered in the lake district on the morning of the 24th, a great bank of high pressure moved across the United States and settled in and over the Bermudas, remaining there until the 27th. Thus while the second storm was pushing eastward on the 24th, an area of high pressure existed off the Atlantic coast, and another area of high pressure existed north of the Great Lakes, and was spreading eastward. On the evening of March 24th, the two areas of high pressure were separated only by a long narrow trough extending northeast by southwest across the Ohio Valley. This trough connected the receding storm with the approaching one, making almost continuous rainfall. On the morning of March 25th, the trough extended from Texas to New England, with centers over Arkansas and the Ohio Valley. The high pressure in the Canadian region and in the Bermudas kept the area of low pressure over the Ohio Valley from moving on to the eastward. On the 26th the southern portion of the trough moved to the eastward and settled over North Carolina. When the southern portion of the trough passed over the drainage areas of the streams that flow into the Ohio River from the south, the latter were also caused to assume flood stages, thus making doubly sure the resultant destructive flood stages on the Ohio River. On the 27th the high pressure over the Bermudas gave away and the area of high pressure in Canada moved over the Atlantic Ocean, thus permitting the areas of low pressure to move on into the Atlantic ocean, relieving the flood-stricken Ohio Valley.

Thus the two storms passed across the Ohio Valley so close together that the rain areas of the two blended, and the second storm was held back by the two 'highs,' concentrating the rainfall for two successive days in the same place, while the southern portion of the trough moved across the southern tributaries of the Ohio, flooding them at the same time. At no time in the history of the Ohio Valley had so much rain fallen in a 72-hour period as fell last March 23–27. In many local areas, as large an amount of rain has fallen in an equal length of time, but never has there been such a heavy rainfall over so large an area in so short a time.

Again it is of special interest that no low temperatures existed immediately before, during or after this period of flood. At no

place in the Ohio Valley was the ground frozen, nor was there any ice or snow stored away in any part of the basin to aid in causing flood conditions.

In Indiana there had been enough rain previous to the downpour to saturate the ground to such an extent that there was no room left for the absorption of the surplus water; and it is hardly possible that the small amount of water absorbed, even if there had been no rain for some time before the downpour, would have made much difference in the height of the flood. A complete history of the meteorology of these storms, with charts and tables, will be found in the publications of the United States Weather Bureau. The above is based on the information taken from these publications.

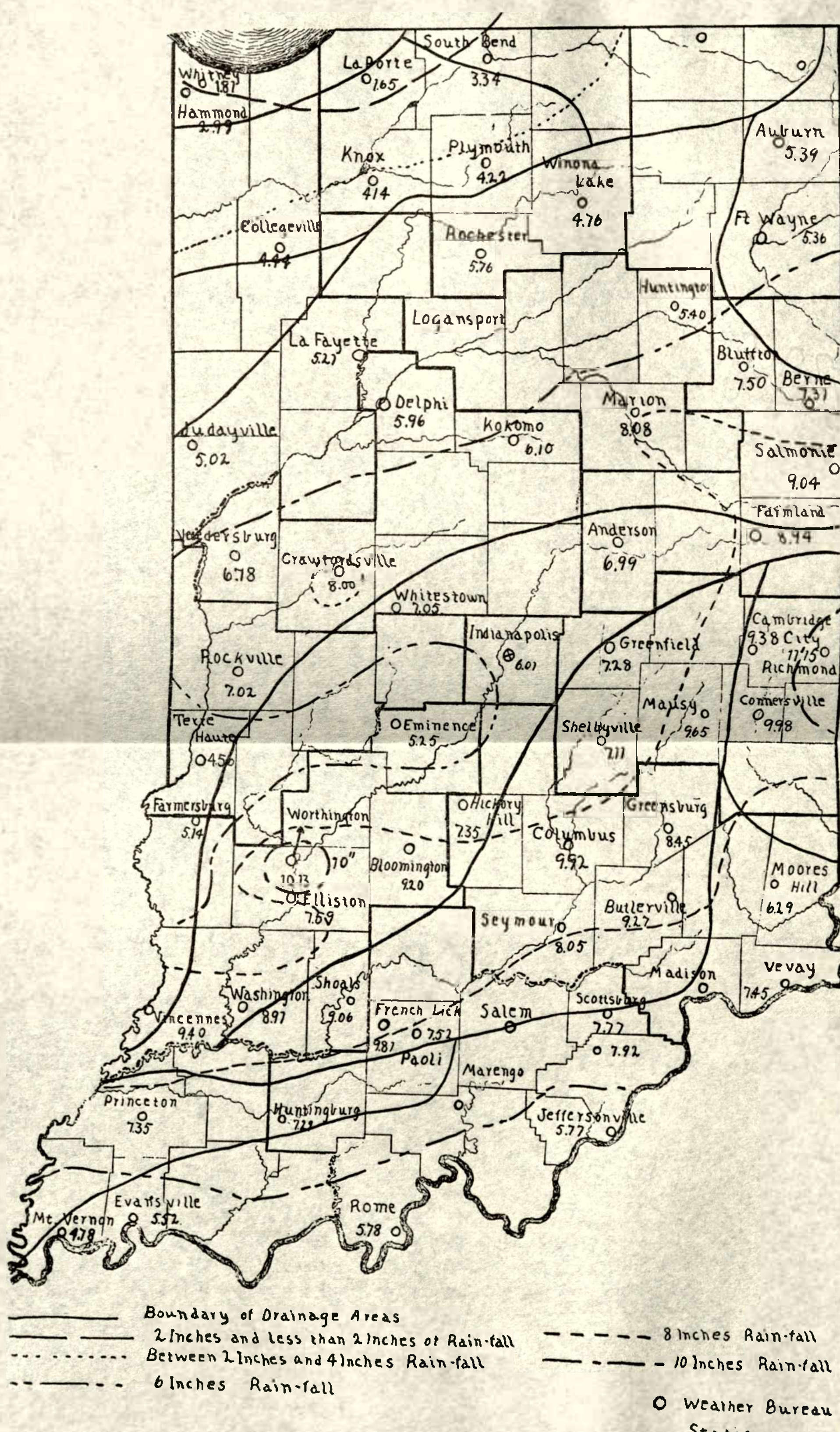


CHART No. 2. Showing drainage basins of the two forks of White River and the rainfall at weather stations.

TABLE No. 2—*Table Showing Daily Rainfall Upon White River Drainage Basin for the Month of March, 1913.*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
West Fork—																															
Anderson	.15	.04	....	.08	....	....	T	T	....	.04	.15	....	.15	.26	....	....	T	....	....	....	.45	....	2.34	1.50	2.51	.50	.14	....	....	....	.19
Bloomington	.31	.02	....	....	.09	.23	....	.03	...	....	.36	....	.01	1.06	T	.05	.03	....	....	.14	1.56	....	.11	.79	6.56	1.12	.62	T	....	....	....
Eminence	.40	....	....	....	.36	.15	....	....	....	....	....	....	.95		T	....	....	....	....	....	.25	....	1.60	1.95	1.45	.25	....	....	....	....	....
Farmland	.25	....	....	.02	.08	.10	....	.01	....	T	.17	....	T	.40	....	.03	T	....	....	.02	.70	....	....	2.97	4.42	.78	.77	....	....	....	.40
Hickory Hill	.26	....	....	.09	....	....	.14	.04	....	....	.05	.23	1.33	....	....	....	....	....	....	.07	.68	....	.42	1.63	4.39	1.04	.05	....	....	....	.50
Indianapolis	.04	....	.01	.05	.09	.02	.05	.01		.25	.01	T	.73	....	.01	.01	....	....	T	....	.46	....	1.27	2.76	1.56	.34	.08	....	....	.01	T
Washington	.20	....	....	.06	....	.12	....	....	....	.09	.23	....	1.17	....	T	....	....	....	....	.36	.85	....	.15	2.08	5.83	.85	....	....	....	....	....
Whitestown	.24	T	.04	.05	.15	....	.02	....	T	.20	....	....	....	.51	T	.01	.02	....	...	T	.62	....	.12	2.98	3.09	.11	.75	....	....	....	.02
Worthington	.27	....	....	T		.17	T	....	....	.30	....	1.00	....	.01	T	T	....	....	T	.07	.72	....	.21	2.26	4.25	.69	.18	....	....	....	....
East Fork—																															
Butlerville	.20	....	....	.12	.11	.07	.12	....	....	.09	.11	....	.25	.77	....	.06	....	....	....	.14	.88	....	.14	2.57	4.43	1.56	.57	....	....	....	.17
Columbus	.26	T	....	....	....	T	....	.10	....	....	25	....	.02	.81	....	....	....	....	....	.04	.58	....	.07	1.72	7.00	1.60	.53	....	....	....	.04
French Lick	.24	.03	....	.01	.15	.17	.02	.03	....	T	.42	....	.01	1.01	....	.02	.01	....	....	.24	.92	....	T	.72	4.85	.79	.16	.01	....	....	T
Greenfield	.40	....	....	T	....	.10	T	....	....	T	.23	....	T	.48	T	T	T	....	....	T	.37	....	1.25	2.56	2.32	1.00	.15	....	....	....	T
Mauzy	.30	....	....	.04	....	.13	T	.12	T	.02	.02	....	.20	.42	T	.10	....	....	....	....	.89	....	.56	2.25	5.59	.98	.27	....	....	....	.01
Nashville	.32	....	....	T	T	.15	.01	....	T	.04	.21	T	.33	.69	T	.05	....	....	T	.12	.80	....	.37	2.02	6.01	.52	.05	....	....	....	....
Scottsburg	.10	T	....	....	....	T	T	....	....	....	....	....	.94	....	....	....	....	....	....	.15	1.08	....	.20	2.69	3.41	1.31	.16	....	....	....	....
Seymour	.20	T	....	.09	.04	T	.05	....	....	.05	T	T	.98	....	T	.02	....	....	T	.09	1.24	....	.08	2.05	5.43	.28	.21	....	....	...	.01
Shelbyville	.32	.04	....	.06	.01	.06	.04	.07	T	....	.24	....	.25	.45		.03	.03	....	....	.08	.50	....	.41	2.06	3.57	.90	.17	.03	....	....	.02
Shoals	.45	....	....	.02	....	.29	T	....	....	....	.36	....	....	1.47	....	T	....	....	.30	....	1.19	....	T	6.66	1.80	.45	.15	....	....	....	....
Greensburg	.25	....	....	....	....	....	....	....	....	....	....	....	.65	.10	....	.01	....	....	....	....	.50	....	.45	3.15	4.01	.84	T	....	....	....	T

TABLE No. 2A—*Summary of Rainfall Upon White River Drainage Basin for the Month of March, 1913.*

	Precipitation for March, 1-22.	Precipitation for March, 23-27.	Total Precipitation for March.	Departure from the Normal.	Greatest Fall in Twenty-four Hours.
West Fork—					
Anderson	1.32	6.99	8.50	4.71	2.25
Bloomington	3.83	9.20	13.03	7.71	6.56
Eminence	2.11	5.25	7.35		1.95
Farmland	1.78	8.94	11.12	7.77	4.42
Hickory Hill	2.89	7.53	10.49		4.39
Indianapolis	1.47	6.01	7.75	3.75	2.76
Washington	3.08	8.91	11.99	6.97	5.83
Whitestown	1.86	7.05	8.93		3.07
Worthington	2.54	7.59	10.13	6.10	4.25
East Fork—					
Butlerville	2.92	9.27	12.36	7.59	4.43
Columbus	2.05	9.92	12.01	8.45	7.00
French Lick	3.28	6.52	9.81		4.85
Greenfield	1.58	7.28	8.86		2.56
Mauzy	2.42	9.65	12.08	8.45	5.59
Nashville	2.72	8.97	11.69		6.01
Scottsburg	2.27	7.77	10.04	5.36	3.41
Seymour	2.76	8.05	10.82	6.46	5.43
Shelbyville	2.18	7.11	9.43		3.57
Shoals	4.08	9.06	13.14		6.66
Greensburg	1.61	8.45	9.96	5.30	4.01
Average for West Fork	2.54	8.36	10.92	6.93	4.85
Average for East Fork	2.32	8.21	10.14	6.17	4.08
Average for both Forks	2.43	8.28	10.53	6.55	4.46

The average rainfall for the West Fork of White River, taken at nine stations, for the month of March, was 10.14 inches. An average of the amount of rain that fell at the above nine stations for the period commencing with March 23rd and extending through to March 27th, is about 80 per cent of the entire precipitation for the month, or 8.21 inches. At seven of the nine stations therefore, an average of 4.08 inches of rain fell on March 25th, or in other words, 50 per cent of the rain that fell on and between March 23rd and March 27th, fell on March 25th, at seven of the nine stations. That is, 42 per cent of the rainfall for the month fell on March 25th.

On the East Fork of White River there were eleven stations that reported to the United States Weather Bureau. During the five days of the flood there was an average of 8.35 inches of rainfall at these stations. The average for the entire month was 10.92 inches. Thus 76.5 per cent of the precipitation for the month fell during the five days of the flood. Also at nine of the stations an average of 4.85 inches of rain fell on March 25th, or 58 per cent of the rain that fell during the five days of the flood fell in one day, i. e., 44 per cent of the rainfall for the month fell in one day.

Taking both drainage areas together, there was an average of 10.53 inches of rainfall for the month of March. During the

FIG. 5. Washout at Summers ditch crossing, Big Four railroad, Evansville to Mt. Carmel division.

FIG. 6. Washout near Summers ditch, Gibson County.

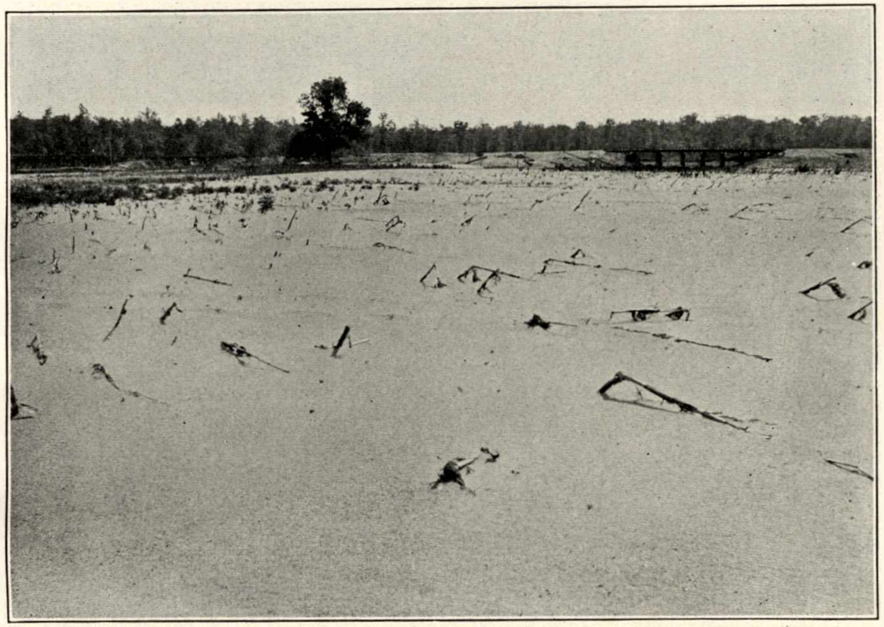


FIG. 7. Deposits of fine gravel and sand. Gibson County.

FIG. 8. A large deposit of sand and gravel, mostly gravel. Gibson County.

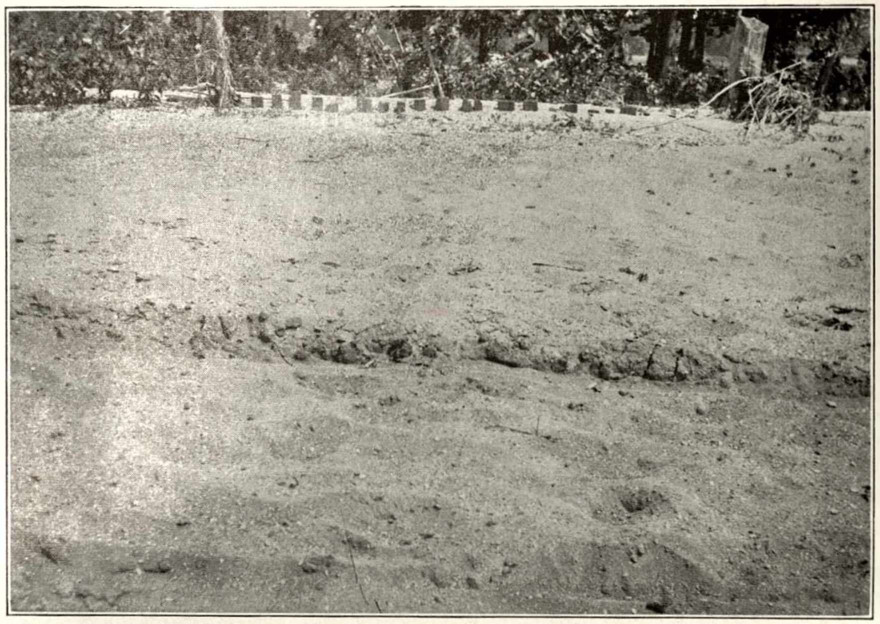


FIG. 9. Deposits near Summers ditch. Picket fence almost covered.

FIG. 10. Sand and gravel deposits in a cornfield. Gibson County.

five days of the flood there was an average of 8.28 inches of precipitation at the twenty stations. That is, 78 per cent of the rain for March fell in five days. Also an average of 4.46 inches of rain fell at sixteen out of the twenty stations on the 25th day of March. There was an equally large rainfall at the other four stations on March 24th. Thus 56.6 per cent of the water, that caused the flood, fell in one day and 42 per cent of the entire precipitation for the month of March fell on one day, March 25th, in White River valley.

The general storm conditions of White River valley were about the same as those of the entire Ohio Valley, which have already been discussed. As was stated above, melting snow, ice jams, and frozen ground did not enter into the consideration of the cause of the flood, as all were absent from the conditions of this State. Neither was abnormal temperature present either immediately before, during, or immediately after the five days of excessive rainfall. However, on March 25th, in the northern part of the State, a light fall of snow occurred, which added misery to all concerned in the flood stricken parts of the different cities. This fall of snow was due to the spreading out of the area of high pressure that was centered over the Great Lakes district.

There is no question but that the flood was caused solely by the enormous rainfall, in the short time of five days, and the fact that 56 per cent of the precipitation fell within the short period of twenty-four hours. If the ground had been frozen, or if there had been floating ice to form jams, or if very cool weather had followed, the deluge, the damage to property and the loss of life would have been vastly greater. On account of the fact that none of these other factors acted in conjunction with the continued downpour of rain, and on account of the fact that the rains came in the latter part of March at a time when there was a minimum of growing crops, or crops in storage, the amount of damage was at a minimum to crops, buildings, and human life. It is difficult to tell whether the soil was washed as badly then as it would have been if the storm had occurred later in the season. The chances are that the soil was damaged more on account of the recent freezing and thawing.

Considering everything, the damage was about as light as it could possibly be, with such an enormous rainfall in so short a time.

Causes of Floods in the Ohio Valley

Floods above the danger line, in the Ohio Valley, have resulted from the following causes, acting alone, or in conjunction:

1. Heavy rainfall over extensive areas.
2. Rapid melting of large accumulations of snows.
3. The formation and the breaking of ice jams.
4. The failure of reservoirs.
5. The breaking of levees.

The first two of these causes acting together are responsible for a very large percentage of the floods that occur during the first four months of the year. A great number of the floods occur during the first four months of the year. For instance, at Paducah, out of the twenty-nine floods that have been above the danger line all have occurred during the first four months of the year. At Evansville, out of the eighty-six floods that were above the danger point, only ten occurred outside of these months; and at Cincinnati, only three out of forty-six occurred outside of the months of January, February, March and April.

The last three of these causes generally act in conjunction with the first two, and in themselves seldom do any great amount of damage over any but a small area. The last flood was caused by excessive precipitation over a large territory, and was not aided in the least by the other flood-causing factors.

Fig. 11. Sand deposits on the east side of White River below Freedom. The hat in the foreground gives an idea of the depth of the sand.

Fig. 12. Sun cracks in sediment deposited at the mouth of McBrides Creek, two miles south of Spencer.

FIG. 13. Shows long rows of sycamore trees along the bank which are beneficial in keeping the bank from being easily washed. Below Romona, Owen County.

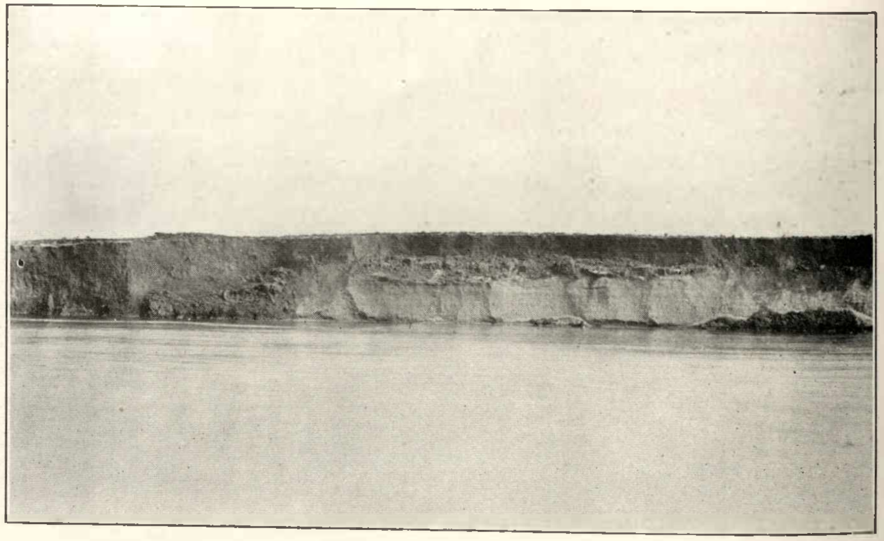


FIG. 14. A typical steep bank at the outside of a meander.

PART II.—OBSERVATIONS

DAMAGE TO SOIL

Soil Washing and Erosion. When the water begins to flow across the flood plain, sand silt and debris are deposited, their position being determined largely by the velocity of the current. In many places where the current is strongest the top soil is removed and in some places great holes are cut.

The amount of cutting depends upon the velocity of the current, the kind of soil, and the amount and nature of the sediment carried in suspension. I. C. Russell, in 'Rivers of North America,' gives the following table on the transporting power of a stream:

TABLE No. 3.

Velocity of Current.	*Size of Material Moved.*
3 inches per second	Fine clay and silt.
6 inches per second	Fine sand.
12 inches per second	Pebbles ½ inch in diameter.
2 feet per second	Pebbles 1 inch in diameter.
2.82 feet per second	Pebbles 2 inches in diameter.
3.46 feet per second	Pebbles 3 inches in diameter.
4 feet per second	Pebbles 4 inches in diameter.
4.47 feet per second	Pebbles 5 inches in diameter.
4.90 feet per second	Pebbles 6 inches in diameter.
5.29 feet per second	Pebbles 7 inches in diameter.
5.65 feet per second	Pebbles 8 inches in diameter.
6 feet per second	Pebbles 9 inches in diameter.

Russell says concerning the above table: 'It must be understood that the currents referred to in this table are bottom currents, and in general may be taken at about half the central surface current.' A study of the table shows that the transporting power increases in a greater ratio than the increase in velocity.

Le Conte, in his 'Elements of Geology,' shows that the transporting power of a current varies as the sixth power of the velocity. Thus, under this law it will be seen that by doubling the velocity of a current the transporting power will be increased sixty-four times. That is, if a stream having a given velocity will carry a pebble weighing two ounces, it will carry a pebble weighing 64 ounces if its velocity is doubled. This law applies only to material held in suspension. Larger materials may be rolled along on the bottom of the stream bed.

Streams, like White River, which have many meanders have their velocities greatly increased when they assume flood stages, and take a more direct course. The water passes over a shorter distance than when it follows the old winding channel, while the fall between the source and the mouth of the stream remains the same at all times. Thus the velocity of the current is greatly increased, making it more effective as an agent in removing the top soil. A very heavy compact soil will be less affected by strong currents of water than a light loose soil, as muck or sandy soil. However, a very compact heavy soil will be readily cut into holes if the current has sufficient tools with which to work. In many places where the current broke across the neck of a large meander great holes were cut, one to two hundred feet in width, five to ten feet in depth, and in several places three or four hundred feet in length. This was the case at Worthington near where the Eel River enters White River. Mr. East is finishing the new channel and will make a permanent cut-off, thus shortening the river three-quarters of a mile. About a mile above Worthington was another example of the current starting to make a channel for itself across the neck of a large meander. In no case did the current cut a new channel all the way across the neck. If these new channels were extended entirely across the neck in the form of a ditch twelve or fifteen feet in width the increase in fall would soon cause the water to enlarge the channel so that it would carry all of the water of White River, thus making a permanent cut-off.

Holes. Where a stump, hay stack, tree, rock or any other obstacle was in the path of the current, the evenness of the current was disturbed and a spiral downward swirl started on the leeward side of the obstacles which acted in the same manner as water in a whirlpool. It was no uncommon thing to see holes in a field where there seemed to be no cause; but upon inquiry we would be informed that there had been a hay stack, stump, rock or post at that place. Figure 3, shows a hole where there had been a hay stack. Farm implements were seen buried or in holes that had been excavated under them, due to the swirling action of the waters as the current passed around the obstacle. Corners of buildings were let down in the same manner. (See Figure 46.) These holes were sometimes ten or fifteen feet in depth and forty to a hundred feet in length. A break in a levee always caused a large hole to be excavated on the lower side of the break. Generally, the material taken from the hole was carried a short distance below and deposited in the form of a sand and gravel bar.

FIG. 15. The current has removed the top soil to the depth to which it is plowed. In the first bend of White River south of Spencer, in the northeast corner of Section 29. The ridges are caused by the land side of the plow. Sand deposit near the trees along the river bank.

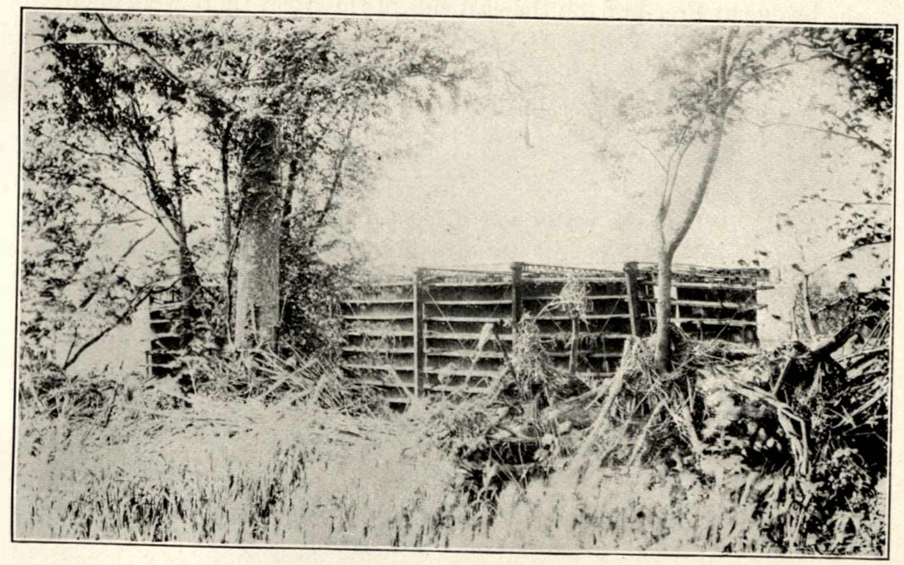


FIG. 16. A thirty-foot bridge that was carried a half mile down stream from the public road north of Brownstown.

Sand and Gravel. When there is a noticeable decrease in the current, sediment is deposited. Gravel and sand in the order of their size and specific gravity, and then the coarsest silt, and last the very fine silt, is the order of deposition. Trees on and near the river bank tend to check the current, causing it to drop the heaviest sediment close to the river, thus building up a natural levee, while the finer silt is carried out to enrich the valley land. There was a tendency for corn stalks to retard the lower current, causing sand to be deposited that otherwise might have been carried on farther. Fences generally had sand deposits on the down stream side. Wire fences caught the floating debris, forming a sort of dam that tended to check the current, and in this way causing a deposit of sand on the lower side, and in some instances on both sides like snow drifts.

It was not uncommon to see as much as twenty-five acres covered with from a few inches to five or six feet of sand and gravel. There were several places where there was as much as sixty and even eighty acres covered with sand. Just below Waverly there was a tract of ninety acres covered. About a mile above Spencer there was about sixty acres, while in the first bend in the river to the south, below Spencer, there was a very large amount of sand. Just below Newberry, there was a tract of about twenty acres, and just below the bridge at Freedom, on the east side of the river, there were about ten acres. (See Figure 11.) Also below 'Blue Hole,' at Washington, there was as much as sixty acres covered with sand, from a few inches to four feet in depth. In most of these cases it will take several years to reclaim this land and get it in good productive condition.

Silt. Where the water was backed up over a considerable area, silt was deposited. The amount of sediment deposited depends on the length of time that the water stood on the ground and the amount of sediment in suspension. The greatest amount of sediment was deposited at the fork of the two branches of White River and at the junction of Muscatatuck with the East Fork of White River. A considerable amount of silt was deposited in the outside of the large meanders, as in the loop at Worthington, where Eel River joins White River. The current from Eel River had a tendency to hold back that part of the White River current that followed the old channel, thus depositing silt and fine sand. Figure 12 shows a small valley just south of Spencer on the east side of the river, in which the back water stood, causing silt to be deposited more than a foot in depth. Mud cracks were developed here in an in-

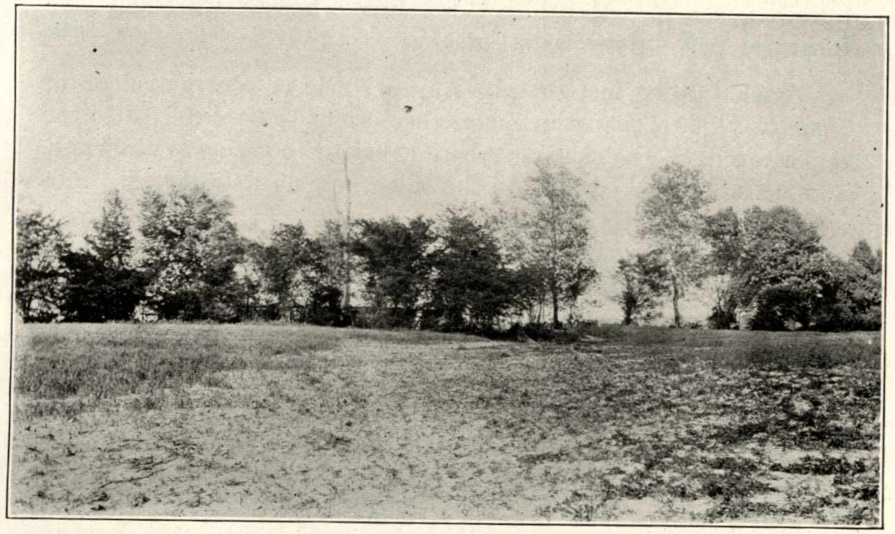


FIG. 17. Middle ground shows where water had stood on wheat in an old lagoon. In the trees is the bridge that had been carried from the road north of Brownstown.

FIG. 18. Top soil washed away and gravel deposited later. Gibson County.

teresting fashion. McBrides Creek flows through this valley and furnished part of the sediment.

Bank Cutting in General. Any obstacle or obstruction on or near the bank of a stream causes the current to be deflected to the opposite side of the channel, where it begins to cut away the bank, and is again deflected back to the side where it first started. This is the beginning of a meander.

Bank cutting causes the velocity of the current to be retarded on account of the increased friction. The increased length of the course as well as the increased load also reduces the velocity of a stream. These conditions, resulting from bank cutting, all tend to reduce the velocity of the stream, thus making the flood stages higher. As a rule, a flood plain is made up of materials that are easily eroded or moved. A great many observations along the river showed that the top soil was from one to ten feet in thickness, while the under layers were composed of sand and gravel. This sand and gravel is easily moved by the current which washes it out from beneath the top soil or loam, permitting the latter to cave in. This accounts for the very steep banks on the outside of the meanders, and for the rapidity with which the current removes the material from the outside of the meander. The sand and gravel is carried to the inside of the meander and deposited in the form of sand bars; this is done in a large measure by the cross currents. The soil is lighter and is carried farther down stream and in many cases carried out and deposited on the flood plain. The sand and gravel has been moved from one side to the other many times. Many beautiful cross sections of large sand bars were seen. Figure 15, shows a typical vertical outside bank of a meander. It seems that the shifting of the stream goes on more rapidly when the bank is just full or only partly full of water, for when the water is over the banks that which is left in the old channel seems to have less erosive power, or at least not any more than when the bank is just full. Even if the rate of bank cutting were the same during the over-flow stages of the river as when the banks are just full, the latter conditions occur much more often than the former, and it is therefore evident that there should be some measures taken to prevent rapid formation of meanders.

Effect of Trees on Bank Cutting. Trees along the river bank will to a great extent retard bank cutting. Sycamores and willows are possibly the best for this purpose. Figure 13 shows the roots

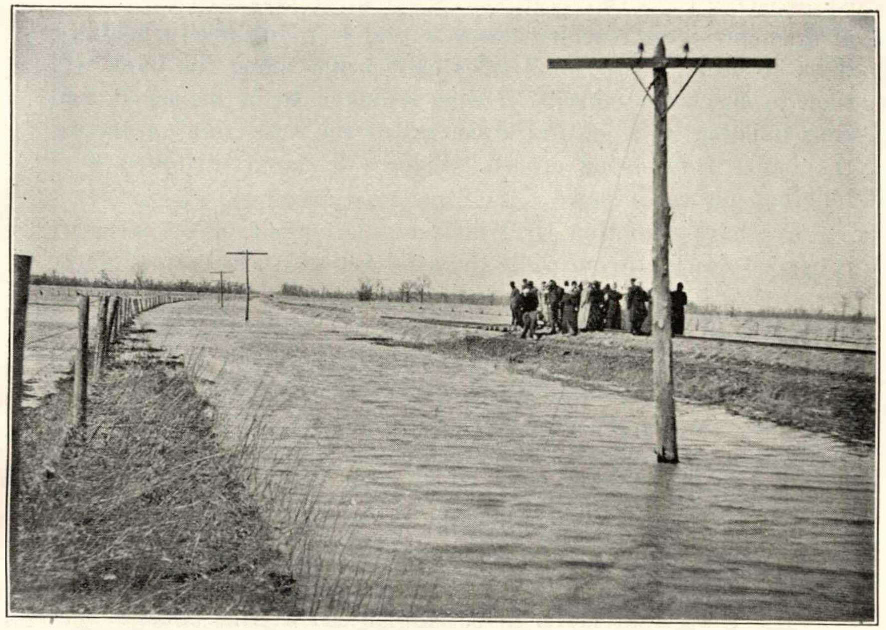


FIG. 19. Before the flood reached the crest. Gibson County.

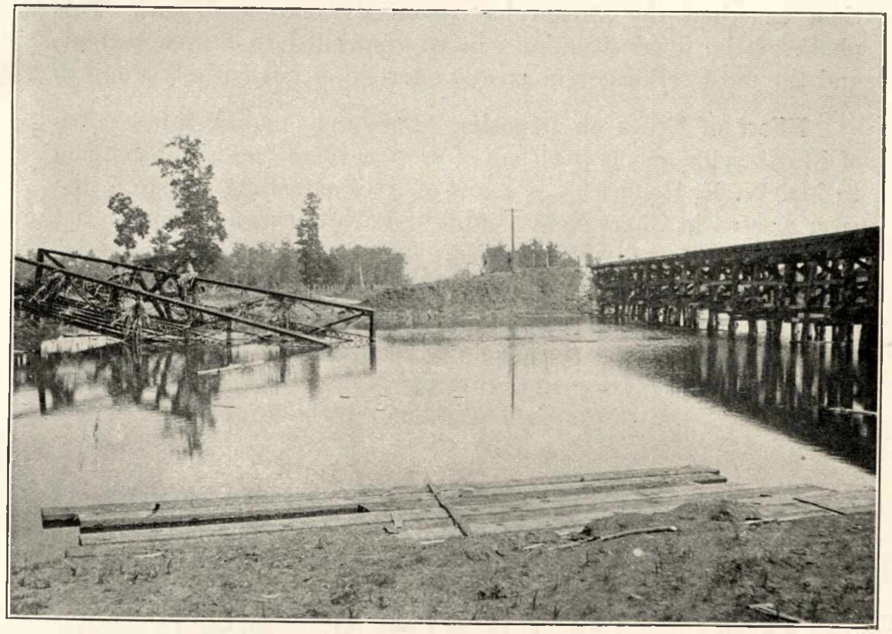


FIG. 20. Hole washed out at Summers ditch crossing. Highway bridge washed out.

of sycamore trees reaching down several feet, helping to hold the bank together. Also small trees and shrubs along the bank will tend to check the current, causing sediment to be deposited, and thus building up a natural levee and at the same time protecting the banks from being eroded. Figure 15 shows this process of building natural levees.

We have seen that the soil from the outside of the meander is carried down stream, while the sand and gravel is carried across the stream to the inside low bank by the cross currents, where it is made into high bars, as seen in Figure 29. In this instance as much as forty acres have been carried from the outside and deposited in the form of a desolate waste, on the other side of the river, in the short time of ten years. It takes many years to reclaim this desolate waste, and after it is reclaimed it belongs to the man who owned land on the other side of the river, the original owner continues to pay taxes on it while the other man farms it. The old saying, 'What is one man's loss is another's gain,' is somewhat applicable here.

The thing that needs to be emphasized at this point is that bank cutting takes place every time that there is a channel full of water, and that the cutting power of the current is as efficient then as when the stream has assumed flood conditions. This phase of the flood situation can be controlled to a great extent, and the most serious cases greatly retarded, if not entirely stopped.

Effect of Trees on Deposits. Two and one-half miles north of Martinsville on the west half of section 19 on the land belonging to Mr. W. E. Hendricks, is a row of trees extending east from the river as seen in Chart No. 2. Mr. K. I. Nutter owns the land east of the row of trees, which formerly extended as far east as the interurban line, but were removed by him. After a glance at the chart the result of the removal is evident. About 90 acres south of the row of trees was covered with silt from one to nine inches in depth, while east of the trees the current was unobstructed and as a result took two to four inches of the top soil from Mr. Nutter's land.

Effect of Grass-Sod on Erosion. Three miles southwest of Spencer on the land of Mr. John M. Dunn, the current left the river and made a short cut across a long meander. Where the current left the river there was a plot of grass some ten acres in extent. The ground covered with grass was not washed or denuded in the least, while the ground below this was robbed of three or four inches

of the top soil. (See Chart No. 3.) Mr. Dunn is of the opinion that it would be better to put the entire bottom land that he owns in timothy, and farm the upland. Considering the price of timothy hay, and the resistance that a good grass sod maintains during flood times, it seems that this would be a very good plan.

Summary of Damage to Soil. The following table gives the amount in acres that was covered with silt, sand, or gravel, and the amount denuded, and the number of acres lost by bank cutting on White River.

TABLE No. 4.

County.	Denuded.	Bank Cutting.	Sand.	Silt.
West Fork.				
Daviess	299	30	77	2,000
Knox	275	28	50	1,000
Greene	1,812	38	256	3,218
Owen	1,699	22	223	289
Morgan	438	27	264	2,370
Total	4,723	145	870	8,850
East Fork.				
Jackson	1,084	9	50	2,400
Washington	143	Very little.	50	300
Lawrence	1,300	Very little.	550	3,280
Martin	1,660	Very little.	50	780
Total	3,127	15	700	6,760
Total for both Forks	7,850	160	1,570	15,600
Estimated loss	At $20 per acre. $157,000	At $75 per acre. $12,000	At $50 per acre. $77,500	

Total Loss in Dollars to Soil $246,500

As far as possible, every farmer was questioned as to the effect of soil wash on succeeding crops. The general consensus of opinion was to the effect that there would be about half a crop the first year, two-thirds the second, three-fourths the third year, and if a subsequent flood did not come there would be a full crop

the fourth year. An ordinary crop on good bottom land is at the very least worth $20 per acre, and on much of it $30 would not be too high. One-half plus one-third plus one-fourth of $20 equals $21.60. This is the basis on which $20 is used as the loss per acre due to soil wash. Thirty dollars may not be too high.

The value of the bottom land varies from $75 per acre to $100 per acre, and there is a greater portion of it worth $100 per acre or more than there is worth less; but it is better to put the price too low than too high. The land lost by bank cutting is a complete loss, hence the loss per acre was placed at $75. The land that is covered with sand and gravel is almost useless for several years, but can be reclaimed after a considerable number of years, so that $50 per acre seems to be a fair estimate of this sort of damage. The farmers say that the ground that is covered with silt does not produce a full crop the first year, but that after the new soil has been frozen the following crop will more than make up for the loss of the first year.

On the West Fork there were some who thought that the sediment which is being brought down in recent years is not so good as that which was formerly deposited over the flood plain. Others could see no difference. The investigators are of the opinion that the silt is not as good as it was before so much of the forest was cut from the steeper slopes. This is especially true of the unglaciated portion of the drainage basin of White River. During the last few years the steeper slopes have been robbed of their forests. The farmers have tried to farm these steep hills and as a result much gullying has taken place. The results of this process is to be seen in the western part of Monroe County and in the eastern part of Greene County. As much as twenty acres can often be found in one area that has been stripped of its grass sod, and numerous gullies have been cut down into the red limestone soil, exposing the limestone below. This soil is easily carried away and when dropped on the fertile alluvial flood plain is not as productive as the finer particles of humus that were gathered from the wooded areas several years ago, and deposited in the same places where the red clay is being deposited by every great flood. To one who has spent three summers studying the geology of the unglaciated part of the State, there is no doubt but that the deposits derived from this part of the White River basin are less productive than formerly and this decrease in productivity is due in a large measure to deforestation. There are several hundred acres in Monroe and Greene Counties that are in the same condition. A fuller report on this

FIG. 21. Public road at Waverly, after the flood. The hole in the foreground was caused by the current enlarging a cellar under a house.

FIG. 22. Large area of sand in the bend of the river west of Spencer. Notice the large sand bar near the trees.

subject will be published later. For a full discussion of the effects of deforestation on erosion, see Mr. L. C. Glenn's, 'Denudation and Erosion in the Southern Appalachian Region, (Professional Paper, No. 72, U.S.G.S.').

Levees and Embankments

One of the most interesting phases in the study of the flood conditions was found in levees and embankments. We will first consider the levees and the embankments as to their relation to the river, their ponding effect upon the flood waters, their effect upon the land, both above and below them, and the effect of the high waters on the levees themselves. Then will follow a consideration of their general effects and conclusions concerning them. They will be taken up in the order in which they came under the notice of the investigators in the progress of the river work. Constant reference to the maps will help the reader to understand the text.

Morgan County. White River in Morgan County flows through the exposed Knobstone sandstones and shales. Since this rock structure is easily weathered and eroded, the valley is remarkably wide, being from one to four miles in width. This great and valuable strip of alluvial land is cut through by the conspicuosly meandering river which does not tend to remain constant in its channel. As a result of this latter condition, man has attempted to hold it in its present channel by means of riprapping and leveeing at different places along the channel. Levees, however, have not been built for that purpose alone, but for protecting the alluvial soil from wash and for the protection of growing crops. We will see with what success these constructions have served their purpose.

The first construction that came to our attention was the public road extending northeast across the valley from Waverly. The water was completely over the embankment which was about ten feet in height in the stretch between Waverly and the cement bridge, a distance of about one-eighth of a mile. On the north side of the bridge it was much less in height. This was a new rock road and was almost entirely destroyed, the rock being carried several hundred feet below and deposited with other debris in a large bar. Next to the town not only was the grade washed out, but a deep hole was made. This was because of a swirl starting from the cellar of a house that was washed away. A very strong current raged at this place, due to the fact that the river turns nearly a right angle

FIG. 23. Looking southwest across White River at Gosport, March 26, 1913; showing ripples as water flowed over Monon track.

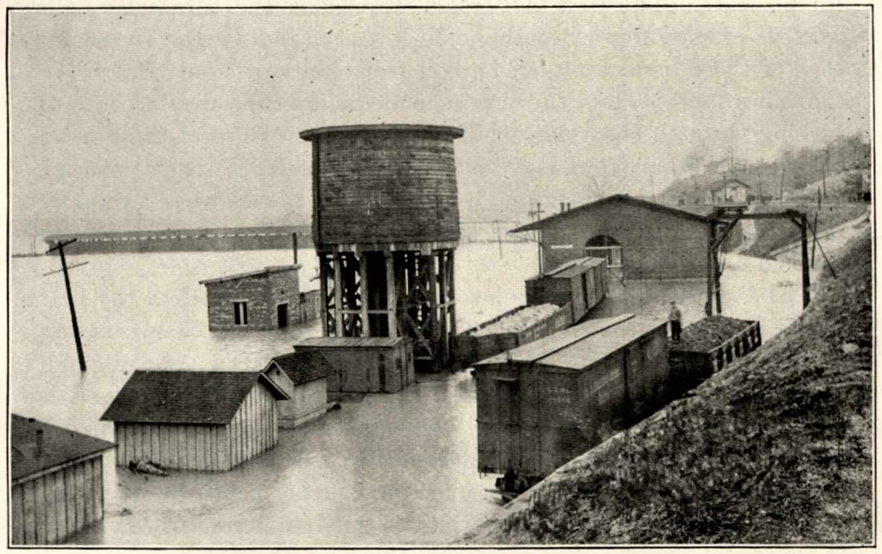


FIG. 24. Monon station, Gosport, March 26, 1913.

just above Waverly, and the overflowing water tended to sweep around the edge of the town in a more majestic course.

The new cement bridge over the river was not damaged, but there is no doubt but that its massiveness and small cross section helped to direct the water to either side. Both approaches to the bridge were washed out. North of the bridge the road was washed away and the rock deposited in the fields below. About a quarter of a mile north of the bridge the largest wash occurred, where a current went across from above. About one acre of land was washed, from two to four feet deep, on each side of the road as a result of the unevenness of the flow caused by going over the road bed.

A small levee planted in trees extended from the bridge to about one-half mile down the river, being parallel with it and about six rods away. This levee did not seem to have any effect outside of keeping the current confined to the river side. The strip of land between the levee and the river was badly denuded.

About two miles southwest of Waverly a small stream enters the river from the west. Parallel with this stream on the section line of 22 and 27 is a large levee extending from nearly one-half mile back to near the river, where it turns at a right angle to follow the river for about one and three-quarter miles. This levee was high enough to be above the waters of the flood, but was broken in three places. The first two breaks were near the turn where the western extension reached the main levee parallel to the river. At each of these breaks occurred a hole from four to twenty feet below the valley land. These holes were made by the concentrated current rushing through the vents made in the levee. Beyond these holes were gravel bars from one to three feet in depth, each covering about an acre of good ground. These two breaks were evidently caused by groundhogs, since several places were literally honeycombed by their burrows.

The third break in this levee was nearly a mile below the first two breaks. This one was very severe indeed. Some twelve to fifteen rods of the levee was entirely swept away and a pond of over a half acre in extent was left in its place. This pond is succeeded by a sand and gravel bar from one to four feet in depth and covering an area of about ninety acres. The bar ends abruptly in a terrace from two to three feet in height, nearly a half mile below the break. A strong current seemed to have hit the levee at this point causing the break, and there might have been a point of weakness here, due to the numerous groundhog burrows. Perhaps as much water flowed through this opening as flowed down the main channel. This alone would account for the immense sandbar below. By consulting the map it will be seen that this was a natural course for the river to take after the levee was broken through. The current took a short course while the river takes a circuitous course to reach the point where the current entered the channel again.

This levee has perhaps done much good in the past and would have done much good this time had it not been broken through. The water would naturally back up from below and cover this large area of some four hundred acres, and being quiet, much silt would be deposited. A levee situated as this one is would be very useful, if well made; but it must be well made, for if it breaks it will bring great damage to the land that it is supposed to protect.

The next levee that demands attention is in Section 5, about two miles below the one considered above. Again a stream comes in from the west, and a levee fifteen feet in height, constructed within the last few years, extends parallel with the stream for about three-quarters of a mile. This levee lies at a right angle to the river. About the middle of the levee a wing extends to the southward for nearly one-half mile, where it joins the river which has circuited to the west, and at the point where the levee approaches, it turns south again. It seemed that a current of water left the main river above the levee and flowed up the small stream. The levee seemed to be sufficiently high, but it broke in two places. The break again appears to have been caused by groundhog burrows. The first break was between the south extending wing and the river. Quite a deep hole was made here and a corresponding sand and gravel bar was made below, but otherwise very little damage was done, since the area included by the main levee, the wing to the southwest, and the river was mostly covered with silt. The main part of the current went by this break to near the western end of the levee where a break of large dimensions occurred. Below the vent and holes, a large bar from one to two feet in depth covered about two acres. Quite a strong current went through this break, denuding a strip all of the way to the Henderson bridge, where the current again joined the river channel.

This levee with its south-extending wing has been valuable in ordinary overflows in causing the land to be silted, but its use, as in the preceding levee, lies in its being unbroken. It should evidently be protected from the ravages of groundhogs.

The conditions at the Henderson bridge were striking. The current was on the south side of the river channel. It was prob-

FIG. 25. White River at Gosport, March 26, 1913.

FIG. 26. Looking south down the Monon railroad tracks after the flood.

ably deflected to this side by the current coming from the big break in the levee considered just above. No water passed across the road north of the bridge. A new road had been made and rocked on a twelve foot grade south of the bridge. This grade was literally destroyed, only remnants remaining. The river channel was widened by one-third on the south side of the bridge, thus leaving the bridge ending some sixty feet out in the river. A new span will be needed to complete the bridge. The current that did the damage came from the broken levee above. Where the road grade was so badly torn away, a great pond from four to twenty feet deep and an acre in area, was washed out. Below this hole some twenty acres of land was covered with sand and gravel one to four feet in depth. Land in this condition is worse than useless. The damage here was several thousand dollars and was due to the constriction of the passageway under the bridge.

The next grade that suffered was the interurban line that connects Martinsville to Indianapolis. A mile or more from the mouth of White Lick Creek, the current left the creek and flowed across the valley. This current damaged the pike road and passing on a short distance washed out about a half mile of the interurban track between Centerton and the river. South of the river the current left the channel, making a direct course across the bend, and washed out about an eighth of a mile more of the interurban track. The telephone and electric line wires were torn down. Little or no damage was done to the soil as the grade was rather low.

The Vandalia Railroad bed was also much injured on both sides of the river. About three-quarters of a mile of track was washed out between Centerton and the river, while south of the river about one-eighth mile was washed out. Here again the grade was rather low and not much damage was done to the farm land. There was some denudation, but it was not due to the grades but to the current taking a more direct course across the neck of the meander.

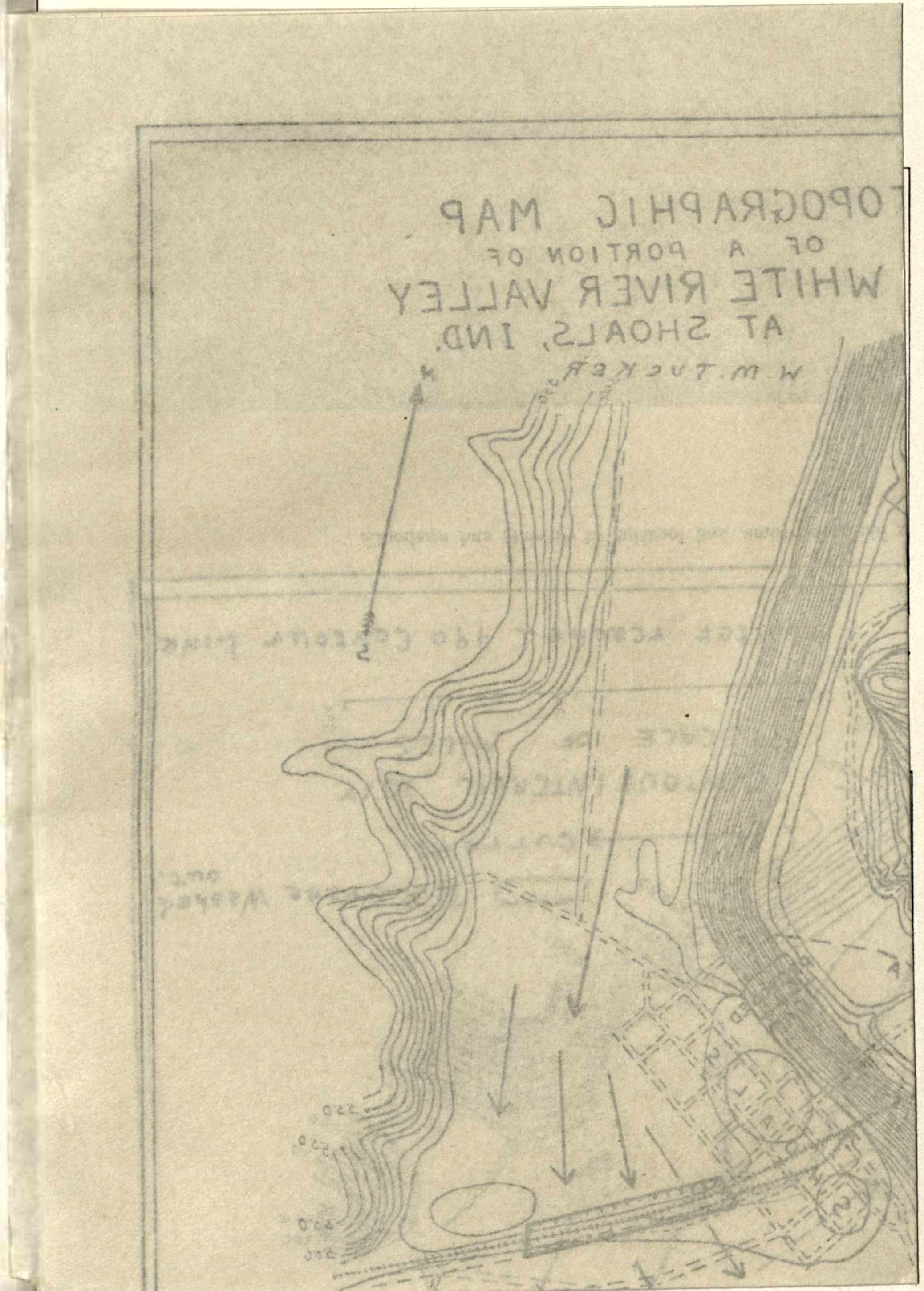
The public road leading northwest out of Martinsville across the valley served as a slight obstruction to the waters and as a result was practically destroyed. The road metal was carried several hundred feet out in the field below and the road bed was washed down to the old corduroy bed. West of the bridge the grade was completely carried away. One pier of the bridge was damaged. Again below the grade there were as usual great holes cut, with the usual sand and gravel bars below.

On the west side of the river about three miles southwest of Martinsville is a high levee about one and one-half miles long,

known as the Bane levee. This levee is built obliquely to the river, coming to the river at its lower end. (See map.) The water did not get sufficiently high to flow over this levee, and it would have been of valuable service had it not been broken in two places. The levee is not planted in trees, but is covered with a heavy blue-grass sod. Some horses and mules were stranded on this levee for several days. The mules attempted to leave and were lost. Near the middle of the levee a break occurred, caused, possibly, by a concentration of the current at this point by a bend in the river just above. This is one of the worst breaks found in the levees along the White River, being second only to the one in the levee first discussed. Where the levee had been, a hole of one acre in area and from five to twelve feet in depth was formed. Below this hole was a huge gravel bar, three feet in depth and five acres in area. The current of water that went through this break went southwest and after flowing two and one-half miles re-entered the river. The current was wide and deposited sediment mainly. It washed only in small patches where there were little elevations on the flood plain. About one-half mile below the break the current encountered a hedge fence against which much drift was piled. This made a veritable levee out of the hedge, but the waters could rush through in many places. This resulted in about ten acres being denuded from six inches to three feet in depth with a great sand bar below.

A second break occurred in the Bane levee near its junction with the river. This break was perhaps less than half the size of the other. It seemed that a great part of the water that flowed through this break flowed up stream (being protected by the levee) and joined the upper current where the land is much lower than it is near the river. The Bane levee was the last of any importance in Morgan County.

Owen County. The flood conditions in Owen County were the most interesting met with along the river. As has been mentioned elsewhere in this report, the geologic structure has been important in the determining of the physiography of the State. Near Gosport the surface rock changes from the soft Knobstone shales to the overlying hard limestones, which are not so susceptible to the weathering agents. Throughout Owen County the valley is bordered by cliffs of limestone and hard sandstone. No longer does one see wide fertile valleys as in the county above. The narrowness of the valley is remarkable. It is from a quarter of a mile to a little less than a mile in width. The water had no opportunity to spread



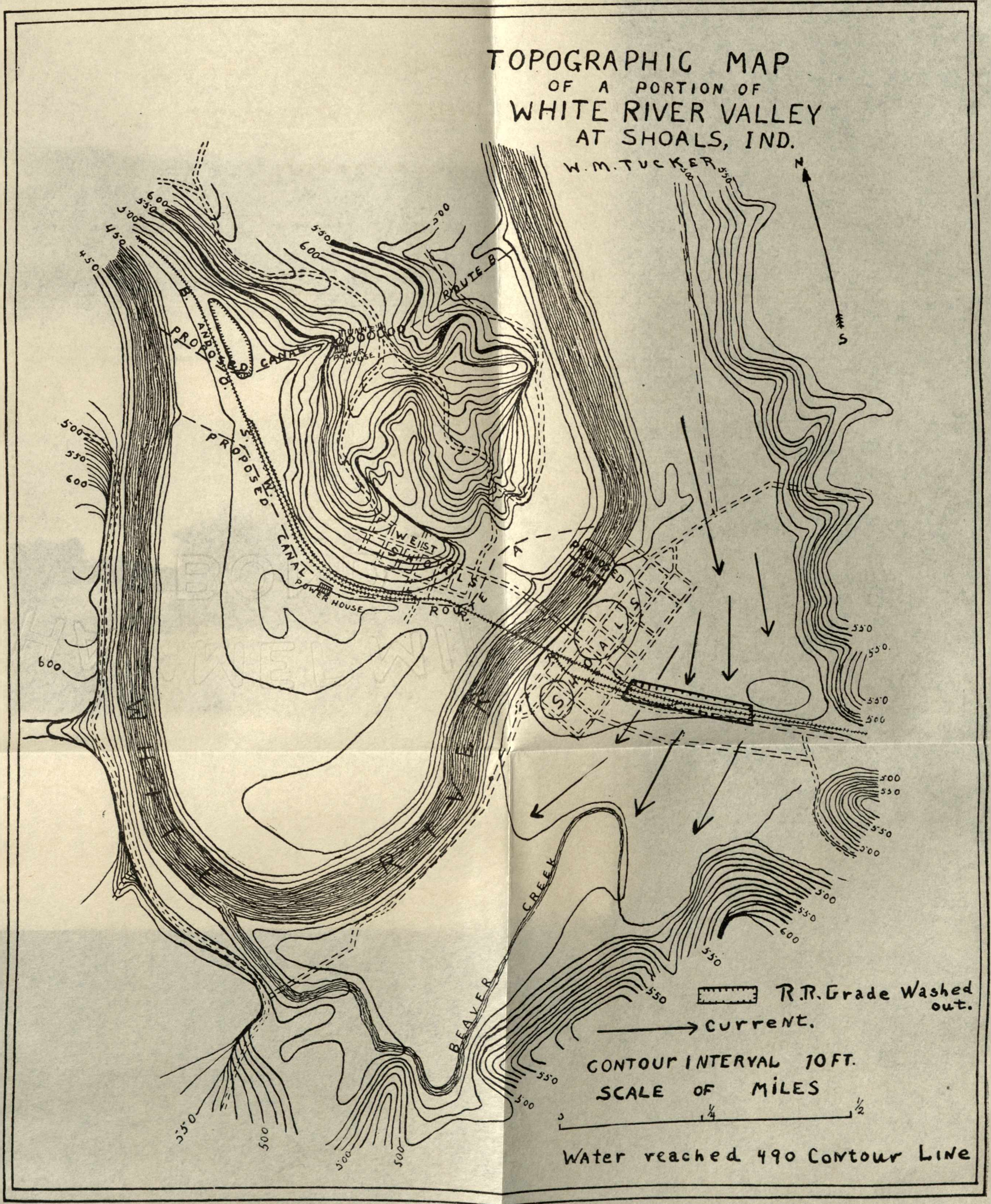


PLATE No. 1. Contour map of vicinity of Shoals, showing bluffs, bottoms, and location of currents and washouts.

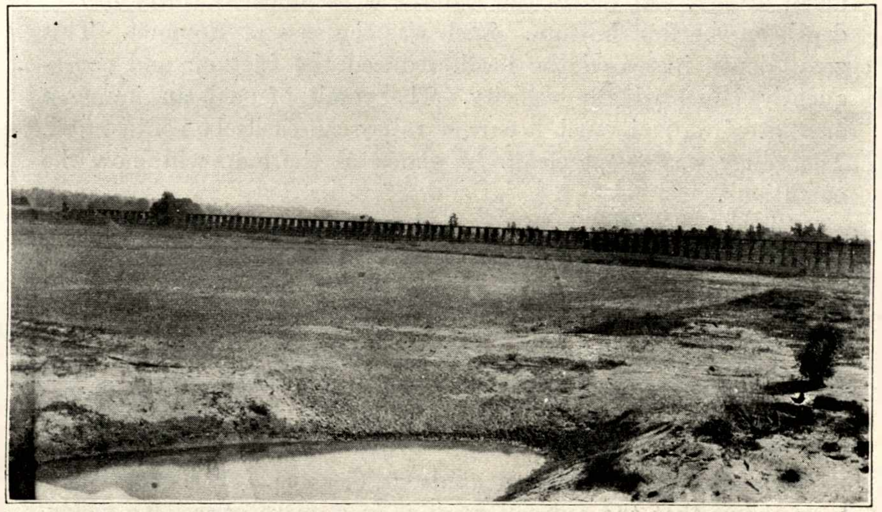


FIG. 27. Trestle of I. C. Railroad at Bloomfield. Neither the trestle nor the bottom land was injured, on account of ample opening for the water to pass through.

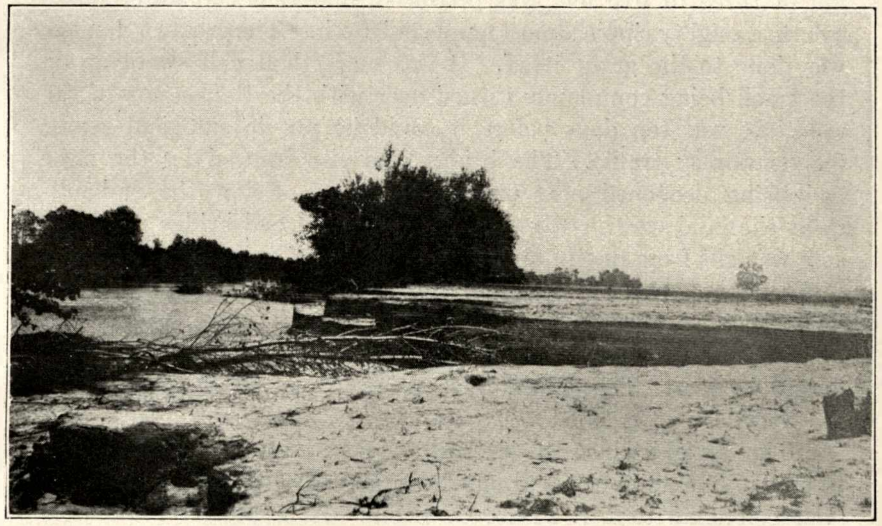


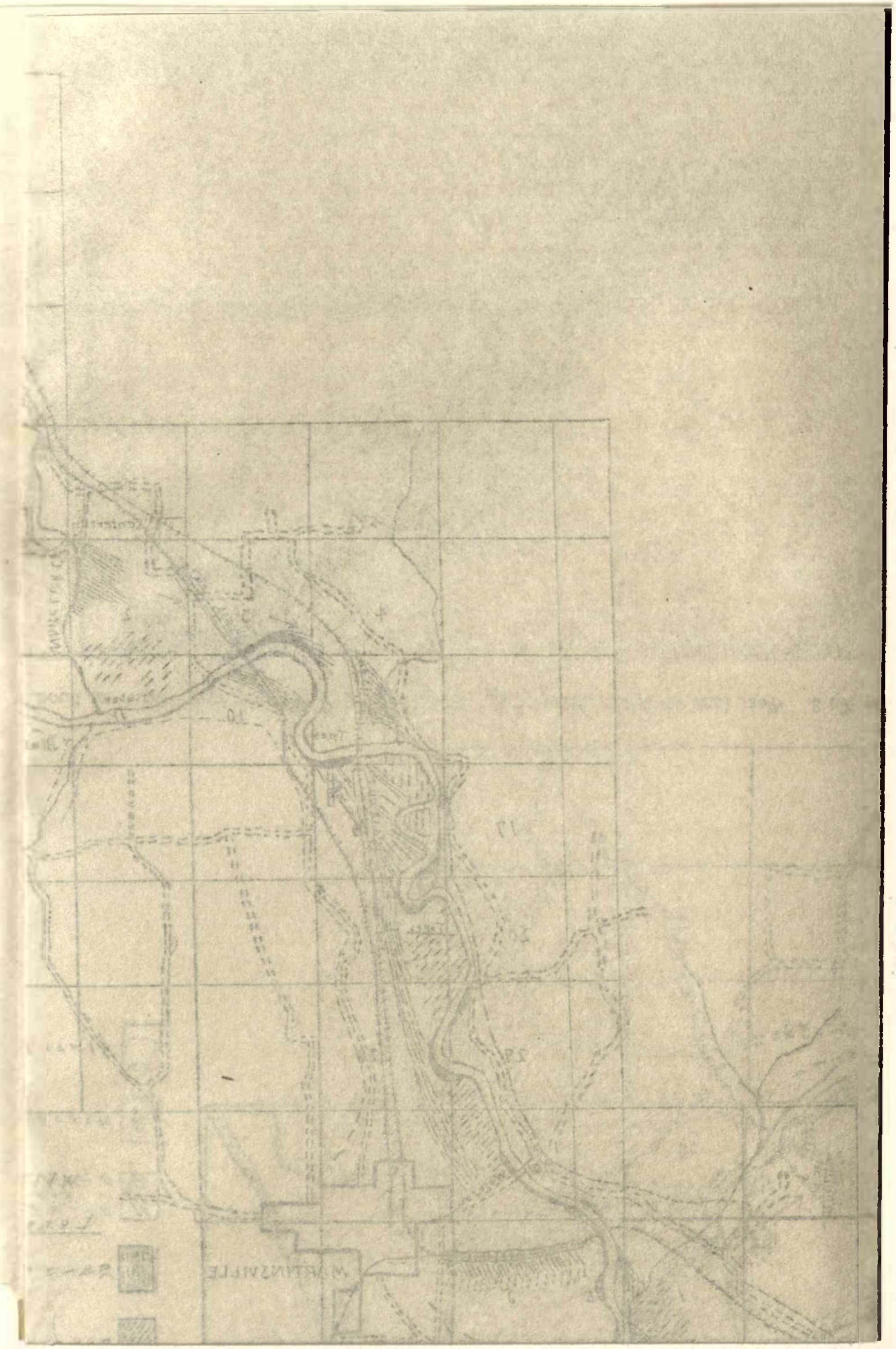
FIG. 28. Bank-cutting west of Newberry, Greene County, on the James Blackmore farm.

over a vast area as in the preceding county, and was consequently much deeper. At places the water was as much as thirty feet in depth on the first bottom. Such was the case at Romona. This great depth increased the head, reduced the friction, and consequently increased the velocity. The result of such an immense amount of water in such a narrow valley can easily be conjectured. The valley was swept clean. A glance at the map will show the conditions.

Since the valley is narrow and meandering, the farm land is not seen in vast stretches, but is in irregular patches of no great extent. There is no such occasion for building levees as there is in the preceding county. Again, perhaps, experience has taught the farmers that levees and embankments do not avail much when it is possible for the water to get thirty feet deep over the valley. At least there are only a few, possibly two, places that demand consideration here.

The first is the Monon grade at Gosport. A glance at the map shows that the railroad grade is in a curve across the valley. The grade is from twelve to twenty-five feet in height, and the only opening is at the bridge over the river, consequently this grade impeded the water and ponded a great amount of it above until it rose sufficiently to flow across. Eye witnesses said that a fall of three to five feet was produced, and that the water broke over in a mighty ripple almost a mile in length. The greatest damage was done to the grade itself. It was more than half swept away, the track being completely turned over with the ties on top of the rails. It was ten days before it could be put in sufficient repair for temporary traffic. The bridge was also injured by the river bed being deepened near one of the piers. Below the embankment the land was heavily silted. At the railroad bridge about an acre was cut from one to four feet in depth. The railroad company suffered the greatest damage here. It seems that there should be at least another section added to each end of the bridge, and to insure traffic against the highest floods there should be some trestle besides. The grade was replaced just at it was before the flood.

The second place of interest in Owen County with regard to embankments is two and one-half miles east of Freedom, on the land belonging to Mr. Frank C. Dunn. Here the river makes a complete semi-circle. It enters Section 23 flowing south, but soon curves to the west, and in Section 22 has curved until it is flowing north. Inside of this loop there are about two hundred acres



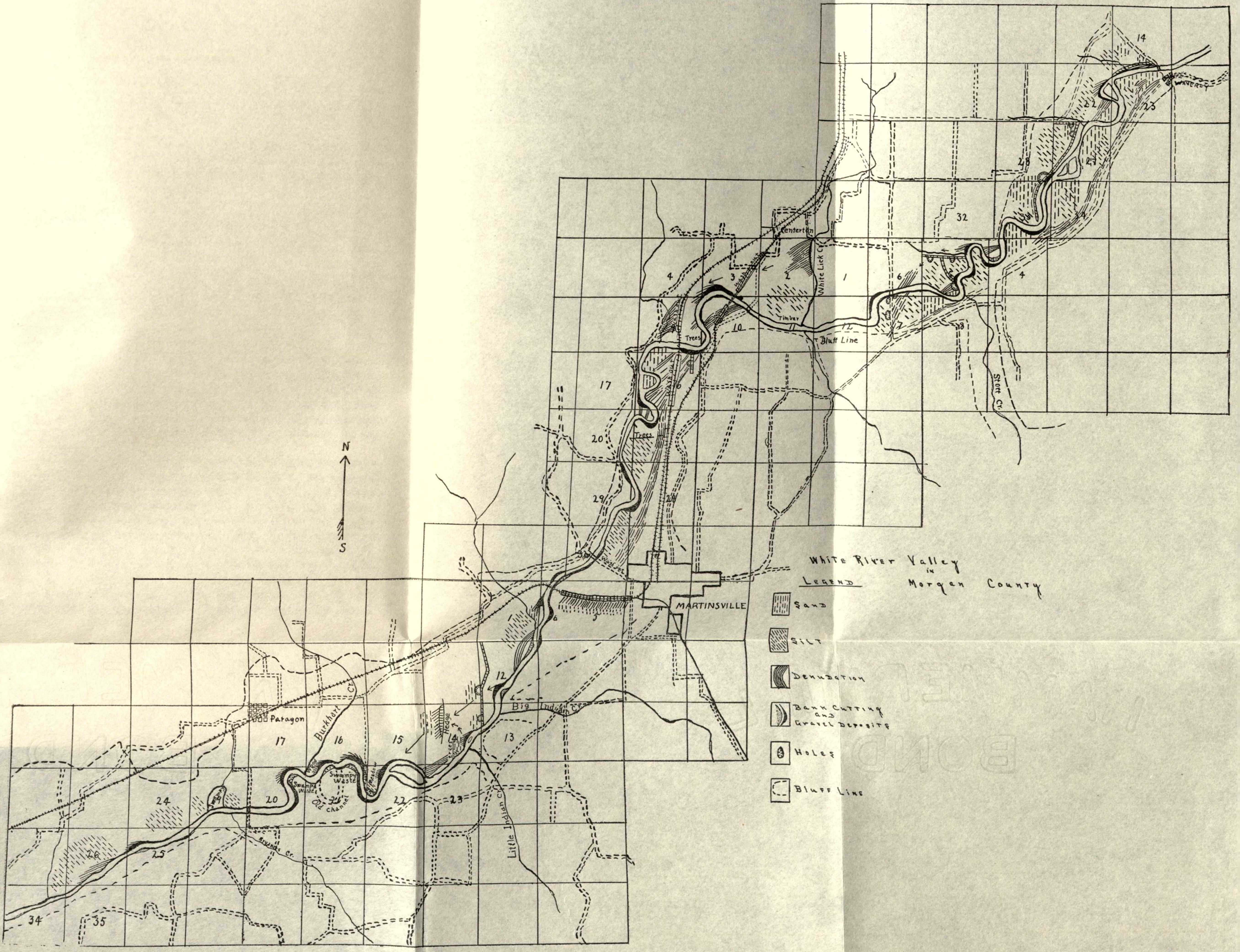


Chart No 3. West fork of White River from Waverly to Gosport, showing effects of flood.

of land of which one hundred and forty acres are tillable. Where the river leaves the bluff at the upper part of the loop, a levee begins and extends parallel with the river for nearly one-quarter of a mile. This levee was almost completely washed out and adjacent to it some four acres of land were cut from one to four feet in depth. Below this badly cut area there were some fifty acres badly denuded, while forty acres were silted towards the western edge of the loop. This levee heretofore had done good service for Mr. Dunn. As long as the water did not get over it, not only was his land in the loop protected, but the water was directed in such a manner as to rob his neighbor across the river and add a corresponding amount to the inside of the bend. Mr. Dunn has declared his intention of rebuilding the levee.

Greene County. In Greene County the river gets wider, and below Worthington it is much wider. This is due to the outcropping of the soft and easily eroded coal measures and to the effects of the Illinois glacial sheet. In pre-glacial times the river ran as much as four or five miles to the west of its present course. It probably ran through the gap that is now occupied by Switz City, thence southward by the present site of Lyons. It seems to have been pushed over to its present position by the great ice invasions of the glacial times. The entire area from Switz City and Lyons eastward to the river is not wholly valley land; it has several great tracts of hill land in it, which are set in the midst of the great alluvial area. The vast stretch of valley land from Switz City and Lyons, southward and eastward to the river was not all under water, but the most of it was near the danger line. Few levees were noticed near the river, but railways and public road embankments offered interesting situations in reference to the flood waters.

In Sections 13 and 14, three and one-half miles east and a mile north of Worthington, a group of levees occurs that demands consideration. They are in a great loop to the south, about which the river runs, coming back northward for a considerable distance. The loop has in it about three hundred acres of farm land. Where the river enters Section 13, a levee was built a year before the flood by Mr. U. G. Clark, who owns the land. The levee which extended along the right side of the river for over a quarter of a mile was washed entirely away. A hole from one to four feet deep was in its former position. The current which left the river here and washed the levee away spread out over and denuded perhaps a

FIG. 29. A huge sand and gravel bar, below the mouth of Veal Creek. The bar is more than six feet above the level of the water.

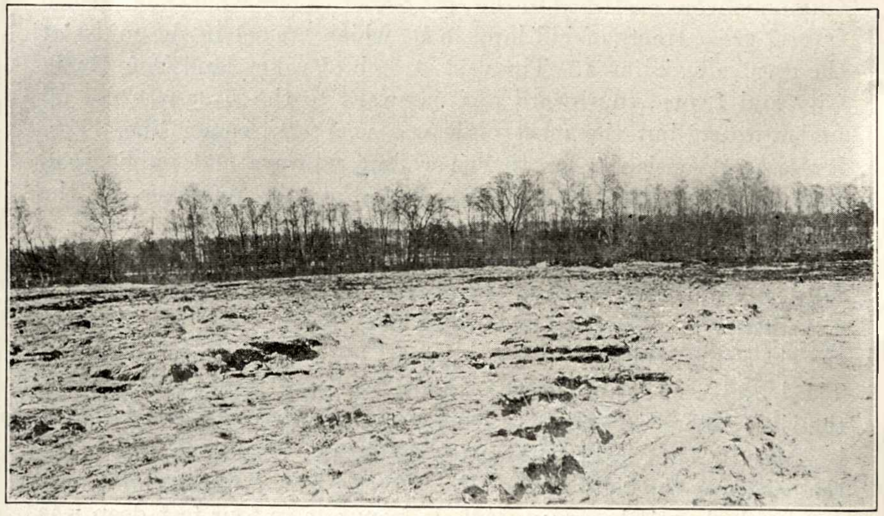


FIG. 30. Soil erosion on James Blackmore farm, west of Newberry.

hundred acres of land in Sections 13 and 14. The wash was worse adjacent the railroad, which follows the foot of the bluff all along the valley. The current in its lower course before entering the river evidently became sluggish, as much silt was deposited in the western part of Section 14.

Farther down in the loop is a levee extending southward some distance from the river, and on approaching the river, which has turned to the westward, the levee turns at a right angle and extends parallel to the river, but some distance removed from it. The west wing of the levee stands much higher above the land than the north wing. The top of it, however, is no higher than the north wing. Presumably the idea is to have no part lower, and to have all parts above the flood stage. From near the turn in the levee another wing extends to the northeast. This extension is considerably lower and a hedge is growing upon it. This levee system was of no service during the last flood. It was broken in numerous places and heavy denudation occurred at the breaks. Much of the intervening land was denuded.

This group of levees has been of much benefit in the past. They were so arranged that they prevented a current from flowing over the land in the loop, but would permit the back waters to come up on the land, thus depositing a heavy silt and enriching the land. They were not built to cope against a flood that would completely envelope them. The question arises whether it would be a paying proposition to construct levees for such exigencies. This will be considered later.

An interesting situation occurs at Worthington. Eel River flows through a narrow gap between the rocky hill of east Worthington and the steep bluff of 'Old Point Commerce,' northeast of Worthington. This gap is about one-eighth of a mile in width. (There is no doubt that Eel River once flowed to the west of the present site of Worthington.) This small gap is dammed by the Vandalia railroad grade, except at the bridge over Eel River, where an opening of one hundred and eighty-two feet is left. The grade is at least twenty-five feet in height. The country north and west of Worthington is really what may be termed 'second bottom,' belonging to Eel River.

During the flood the water from Eel River had to go through the narrow opening in the Vandalia railway grade. The opening was too small to carry the water and as a result the water was ponded at least three feet higher on the upper side of the bridge than it was on the lower side. The E. & I. R. R. grade running northwest

from Worthington prevented the pent-up waters from escaping over the 'second bottom' west of Worthington, but finally the slight grade gave way and the excess water of Eel River found an outlet to the west of Worthington, down Morgan ditch or Dead ditch, which does not get its ordinary flow of water into White River until near the vicinity of Bloomfield. This release of the water of Eel River caused the water which had been ponded above the Vandalia Railroad grade to fall, but it was this water that flooded the western part of Worthington, thereby doing much damage.

It is evident from the above that the E. & I. R. R. grade for a time protected Worthington from an overflow, and if this grade had been higher and firmer, Worthington would have been safe from the overflow. It is evident also that the Vandalia grade was an obstruction to the free passage of the waters of Eel River, and was a direct agent in the flooding of that city. Without doubt the opening in the Vandalia grade at the bridge should be made longer. This argument is much truer since Mr. Z. I. East h- prolonged Eel River nearly one-half mile by directing the channel of White River across a loop, thus shortening its course and causing the old channel of White River to become the Eel River chann-' for one-half mile.

In the matter of embankments, the situation at Bloomfield i striking. A public road and two railroads cross the valley he at right angles and all within a short distance of each other. Th public road with a grade some twelve feet in height comes fi on the north side. The Illinois Central Railroad crosses mostly on trestle work a short distance below. The Monon Branch Railroad is just a short distance below the Illinois Central grade. The Monon grade is made almost entirely of stone and is ten or twelve feet in height. There are very few openings in the Monon grade with which to accommodate the flood waters. Some distance above the public road the river swings from a middle position in the valley to the western side, and after passing the three constructions mentioned, it makes a great long loop to the south and finally swings back almost to the Monon Railroad. Then the river turns again, flowing along the Monon grade a short distance until it is deflected southward by the bluff. The meander here makes a letter 'S' with the top of the letter to the west. (See Chart No. 5.)

It might be mentioned again here that the Illinois Central grade has no effect upon impeding the flood waters, since it is composed mostly of trestle work. A short stretch of the trestle

FIG. 32. West of Brownstown. The channel here is more than 40 rods in width. The opposite bank is being cut away very rapidly while the bank on the right of the picture is being extended in the form of a low sand bar.

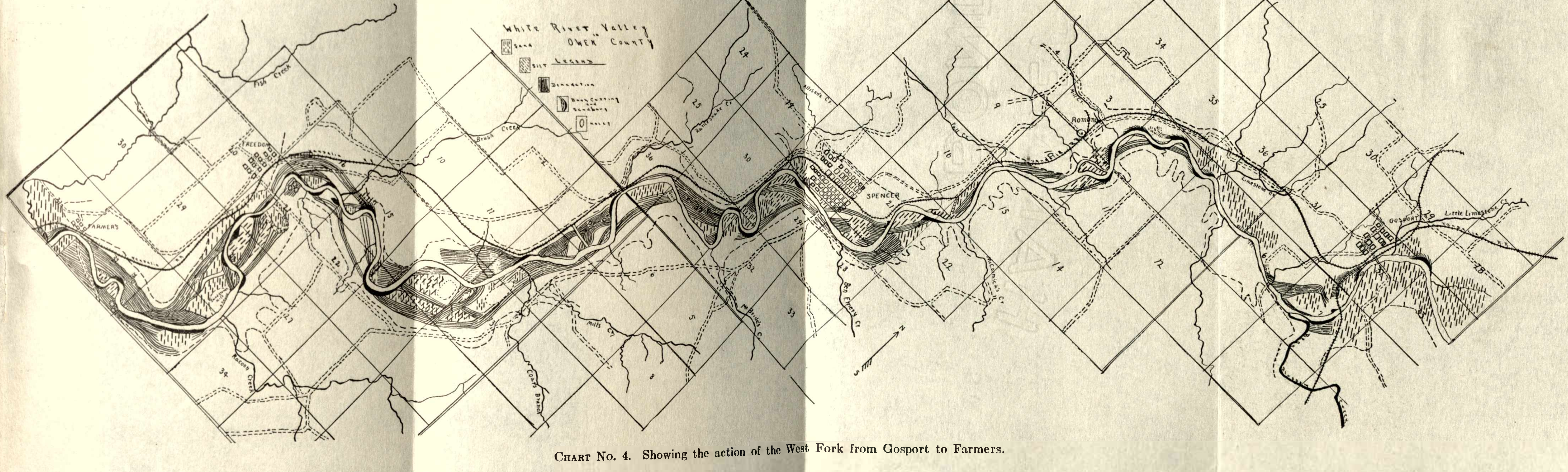


CHART No. 4. Showing the action of the West Fork from Gosport to Farmers.

from Worthington prevented the pent-up waters from escaping over the 'second bottom' west of Worthington, but finally the slight grade gave way and the excess water of Eel River found an outlet to the west of Worthington, down Morgan ditch or Dead ditch, which does not get its ordinary flow of water into White River until
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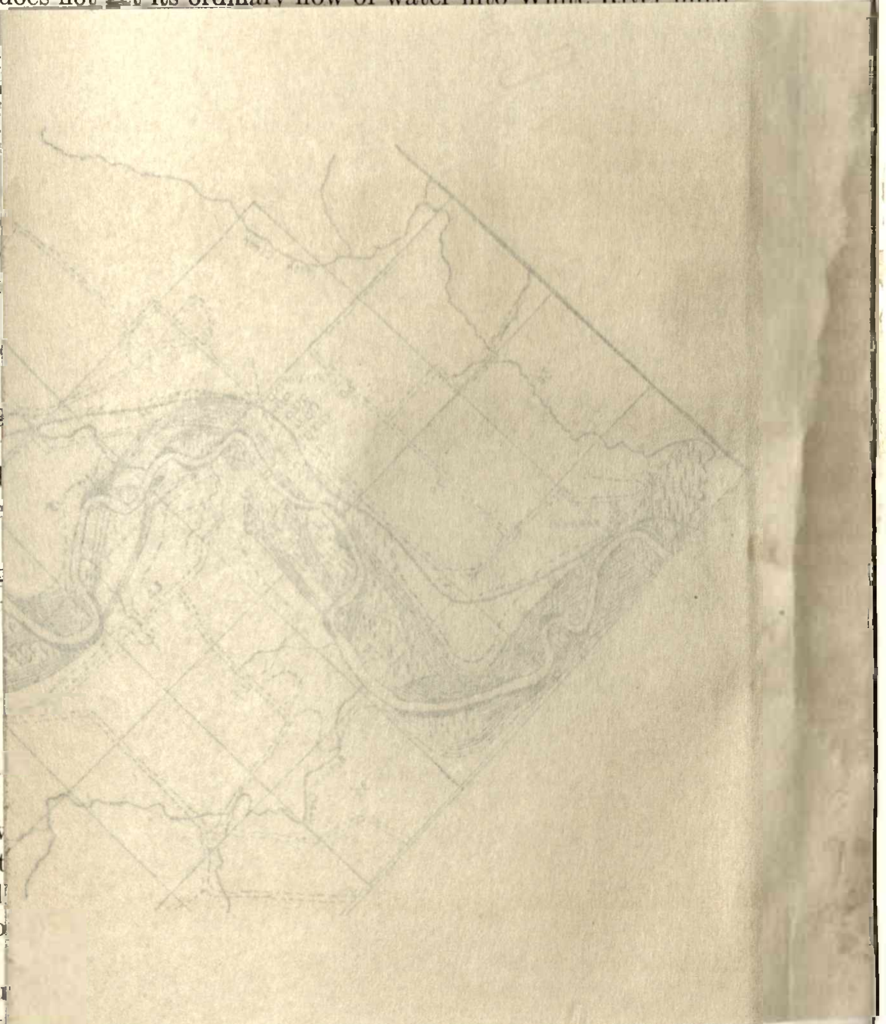


It might be mentioned again here that the Illinois Central grade has no effect upon impeding the flood waters, since it is composed mostly of trestle work. A short stretch of the trestle

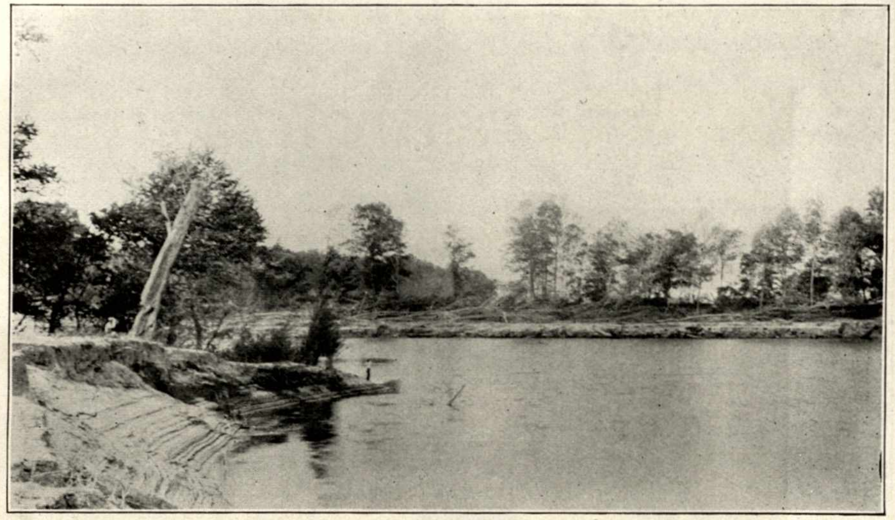


FIG. 31. Junction of the East and West Forks of White River.

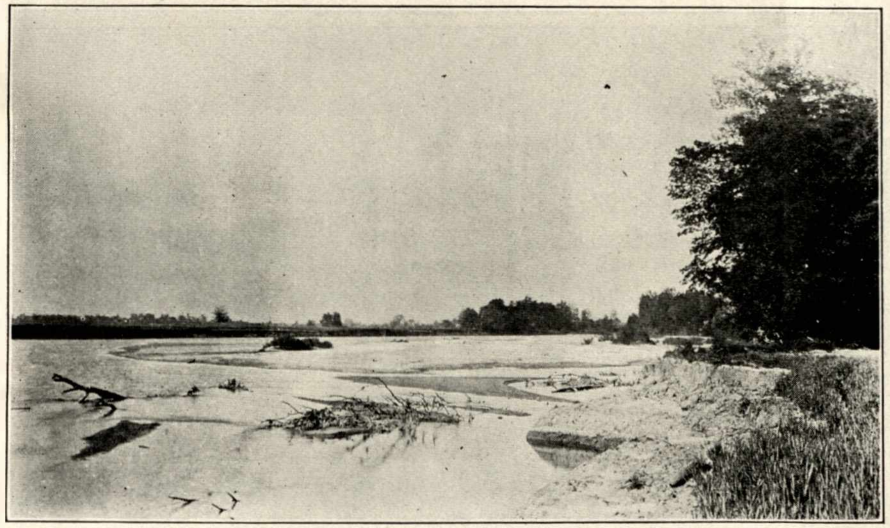


FIG. 32. West of Brownstown. The channel here is more than 40 rods in width. The opposite bank is being cut away very rapidly while the bank on the right of the picture is being extended in the form of a low sand bar.

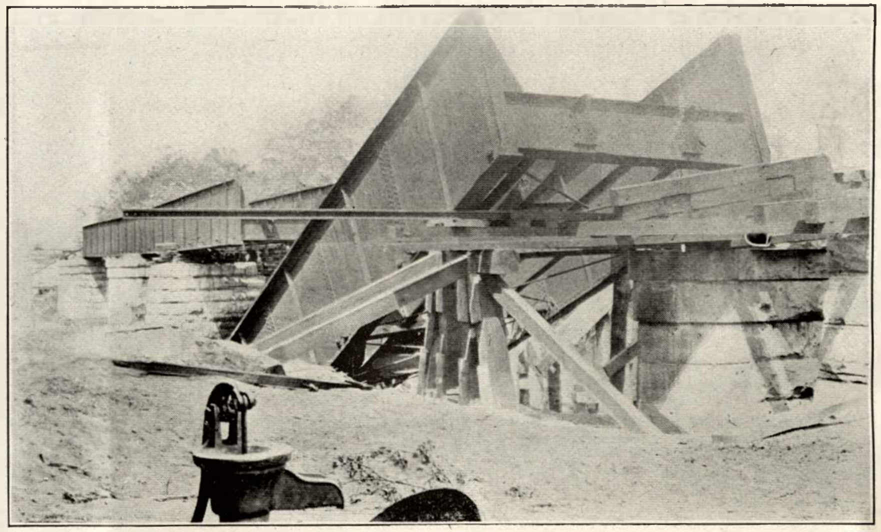


FIG. 33. B. & O. Railroad bridge across White River, above Medora.

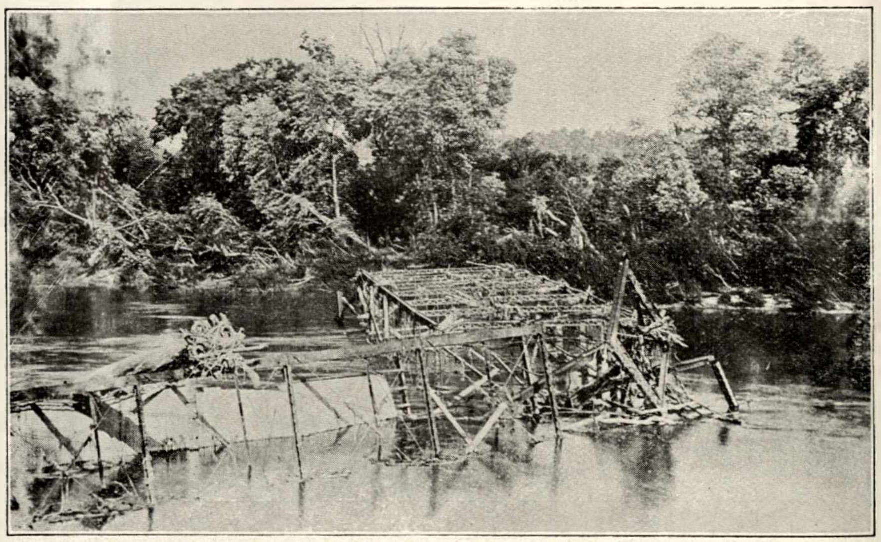


FIG. 34. Public road bridge at Rivervale after the flood.

work and part of the grade were carried away near the eastern end where a strong current raged along the bluff. In a very short time they had trains crossing on schedule time.

The public road grade broke in spite of all that was done to save it. It also broke near the western side of the valley, as the grade was lower at that point. About one-third of the material of which the grade was constructed was washed away and the part remaining was cut and washed to the extent that it was impassable for more than two months after the flood. This grade has been rebuilt and paved with cement and this will make it able to withstand the floods of the future. Immediately below this grade the soil was removed, but only for a short distance, as the current was checked by the Monon grade.

The Monon grade, though it was constructed of rock, fared very badly. Just below where the Illinois Central trestle was injured, the grade was entirely swept away. The raging waters tore up much of the grade between this point and the river bridge, and removed all of the track from the grade. It was more than two months after the water had gone down before the road bed was sufficiently repaired for traffic to be resumed. This was quite a contrast to the Illinois Central Railway, which resumed traffic in less than four days.

Below the Monon grade great holes were cut and the land was denuded very severely below these holes. It would have been much worse if it had not been for the peculiar return of the main river current in forming of the above mentioned letter 'S.'

In the southern part of Greene County, just opposite Newberry, is a grade similar to the road grade at Bloomfield. It is some eight to ten feet in height and goes directly across the valley from the bridge next to the bluff on the southern side of the valley. There are, however, two openings in the grade over which are steel bridge spans. About one-third of this grade was removed from the top for over one-half mile. All of the rock was removed and part of the grade that remained was badly cut and washed. The grade was still unrepaired two months after the flood. The land was considerably washed both below and above the grade.

About fifty rods below the road at Newberry is a high levee with a strip of trees and bushes before it and on it. It is built at right angles to the river and parallel to the road grade. It does not extend quite to the river, and lacks several rods of extending to the bluff at the other end. As a result, the water rushed around it at both ends. Many trees and bushes kept the land from being

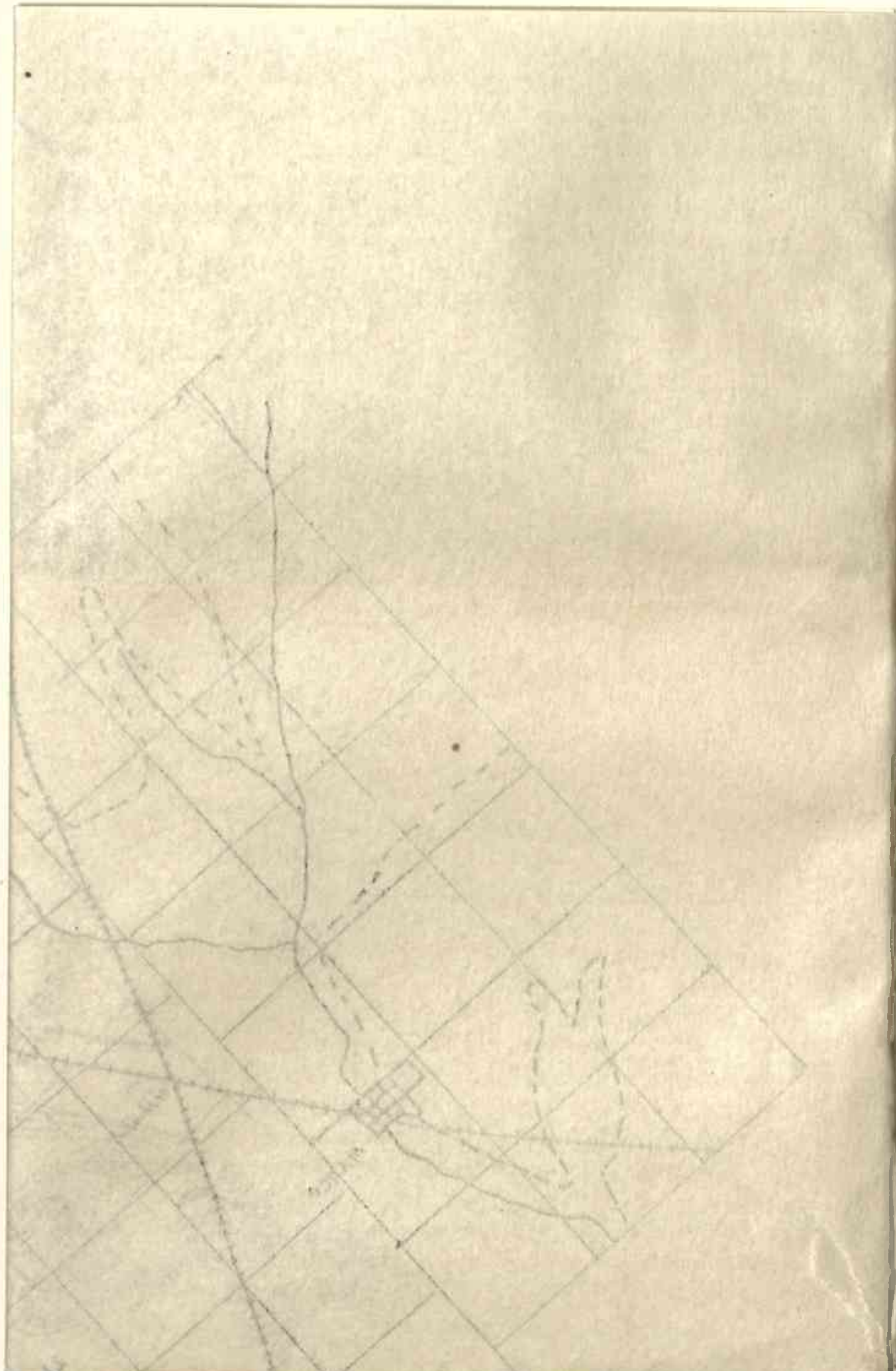
cut or washed at the river end of the levee, while at the other end where there were no trees, the land was washed very badly for some distance below. To the leeward of this levee about eighty acres was covered with a heavy deposit of silt. In some places the silt was over a foot in depth. This levee was not built with the intention of protecting the valley land, but was built years ago in connection with the old canal between Terre Haute and Evansville.

It is interesting to note the situation where the C. T. H. & S. E. railroad crosses the valley in southern Greene County and northern Daviess County. Long stretches of trestle work are frequent and at the river there is a long stretch. The trestle work permitted the water to pass by, practically unimpeded. Consequently little or no damage was done to the railroad or to the land either above or below the grade. The advisability of trestle work was clearly shown here.

Knox and Daviess Counties. White River, between Knox and Daviess Counties, is a long series of meanders in a wide and dismal stretch of valley land. For as much as three-fourths of the distance no upland is visible from the river. The valley land seems so plentiful that little care is taken of either its improvement or its protection against the meandering river. Each year acre after acre of this fertile land is taken from the outside of the numerous meanders, and corresponding low sandy wastes are made on the inside of the meanders. If this meandering could be stopped, or the river straightened and kept straight, hundreds of acres of fertile land could be utilized, which now are either sandy or swampy waste areas. But the valley land is, perhaps, yet too plentiful for such measures to be considered.

The flood damage between these two counties was not so great as might be supposed, since the valley is so wide the waters spread out in some places as much as five miles. This prevented it from being very deep and from being confined in definite currents, except locally. It was only locally that the soil was denuded by the current passing over it. The greatest damage was in the bank-cutting on the outside of the meanders. As bank-cutting is no worse in times of flood than when the banks are just full, or partially full, the flood did no more damage than any other ordinary high water, so far as soil wash was concerned. The problem of bank-cutting lies in straightening the river and then keeping it straight. It is a question as to whether the benefits derived would meet the cost of keeping it straight.

Chart No. 5. West Fork from Farmers to region below Newberry.



In regards to levees and embankments very few were present for consideration. The levees near the river were insignificant and seemingly had no effect for bad or for good. Only one embankment occurs that deserves consideration. Outside of the damage done by bank cutting, nearly as much damage was done below the B. & O. Railroad grade near Washington as was done within the entire river scope of the two counties. The grade is high, being perhaps twenty feet on the average. There is no trestle-work west of the river and very little east of it, thus compelling the enormous amount of water to rush under the bridge. The central pier was washed out and the steel bridge collapsed. Nearly a mile east

FIG. 35a. Frogeye, in Shoals, looking south.

of the river there was a short trestle-work across a hole known as the 'Blue Hole.' This trestle-work was carried out and part of a train was carried down with it. Four lives were lost here. The bodies of two of the victims were not found until two weeks later, when they were found under several feet of sand. Below this 'Blue Hole' sixty acres were covered with sand from a few inches to five or six feet in depth. On the west side of the river just below the bridge two acres were cut from the bank where the water rushed against it in coming through the opening under the bridge. Large trees were washed out and carried away. Six hundred acres were denuded, and forty acres of wheat were washed away, and eighty acres were covered more or less unevenly with white sand.

Most of the damage done here was due to the railroad grade. Had there been sufficient trestle work the damage would have been slight. Despite all of this, no trestle work is being constructed.

East Fork of White River. That part of the East Fork of White River which was investigated as to the flood conditions has only a few features in common with the West Fork. In the first place, the waters were much higher, mainly because of the superior abundance of rainfall within its basin; secondly, because of the narrowness of the valley itself, which is very similar to the West Fork in Owen County; and thirdly, because of slighter fall.

Fig. 35b. Frogeye, in Shoals, looking south.

The region above the junction of the Muscatatuck River with White River, is similar to the Morgan County region of the West Fork. Here the valley is wide for the same reason that the valley of the West Fork is wide, i. e., it is in the Knobstone region, with its soft and easily eroded sandstones and shales. Below Sparksville the valley ranges from less than a quarter of a mile in width to about a mile. It seldom gets over three-quarters of a mile in width, and generally is about one-half mile wide. Through this latter region the valley is really a great meandering groove with the river passing from one side to the other as the entrenched meanders of the valley turn in one loop after another. The channel itself has for ages, so to speak, remained in its present site. It does not cut

its bank on the outside of the great meanders, because the outside of these meanders is the outside of the valley itself, and is usually a steep rocky wall, one to three hundred feet above the stream.

There were no levees noticed in the stretch of river between Brownstown and Shoals, but there were a few railway embankments that need consideration. The first of these is the Baltimore and Ohio Southwestern embankment near Medora in Jackson County. The valley here is nearly three miles in width. It is in the Knobstone region. This B. & O. grade across the valley will average some fifteen feet in height. There are no trestles east of the river and only three or four short stretches to the west of the river. The grade comes to the bank of the river on both sides. As a result of this inadequate trestle-work, as much as a mile of the grade was washed out, or partially so. The short stretches of trestle-work on the west side of the river were washed out on account of the concentration of the current at these points. The second pier from the east end of the bridge was undermined and the structure collapsed. (See Figure 33.) The land was badly washed below this grade, and sand and gravel were deposited in several places. On the west side of the river ten acres were covered with sand from a few inches to three feet.

Before the grade broke, the water was much higher on the north side than it was on the lower side. This caused the village of Medora to suffer considerably. This condition was due to the inadequacy of the trestle-work. If the water could have passed freely, much damage would have been avoided, and several thousand dollars would have been saved the B. & O. Railroad.

The B. & O. bridge over White River south of Bedford was not damaged, but about two hundred feet of the high grade on the south side of the river was removed. (Fig. 3 shows the crew replacing the grade instead of putting in trestle-work.) It seems that these grades should be replaced with trestle-work, but it may be less expensive to have traffic tied up for short intervals, and to build new bridges than to go to the expense of putting in trestle-work.

The Monon Railroad crosses the valley at right angles, three miles south of Bedford. There is no trestle-work here. The grade approaches to the very river banks. As a result considerable stretches of the track were washed out. Again the grade was rebuilt and no trestle-work installed.

The situation at Shoals is very peculiar. The special plate shows the relations. As can be seen, the part of the town east of the river is built on a hill situated in the middle of an alluvial

FIG. 1. Showing hole cut by current where it passed over a levee. One mile south of Romona.

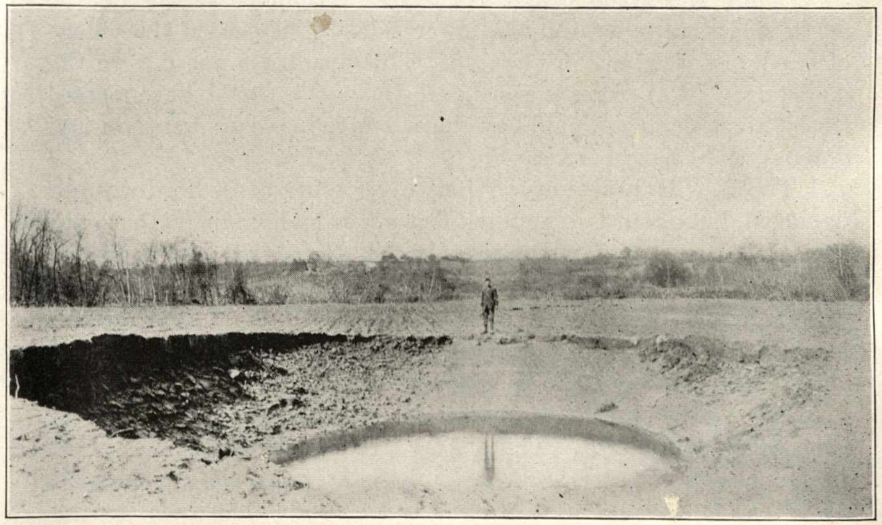
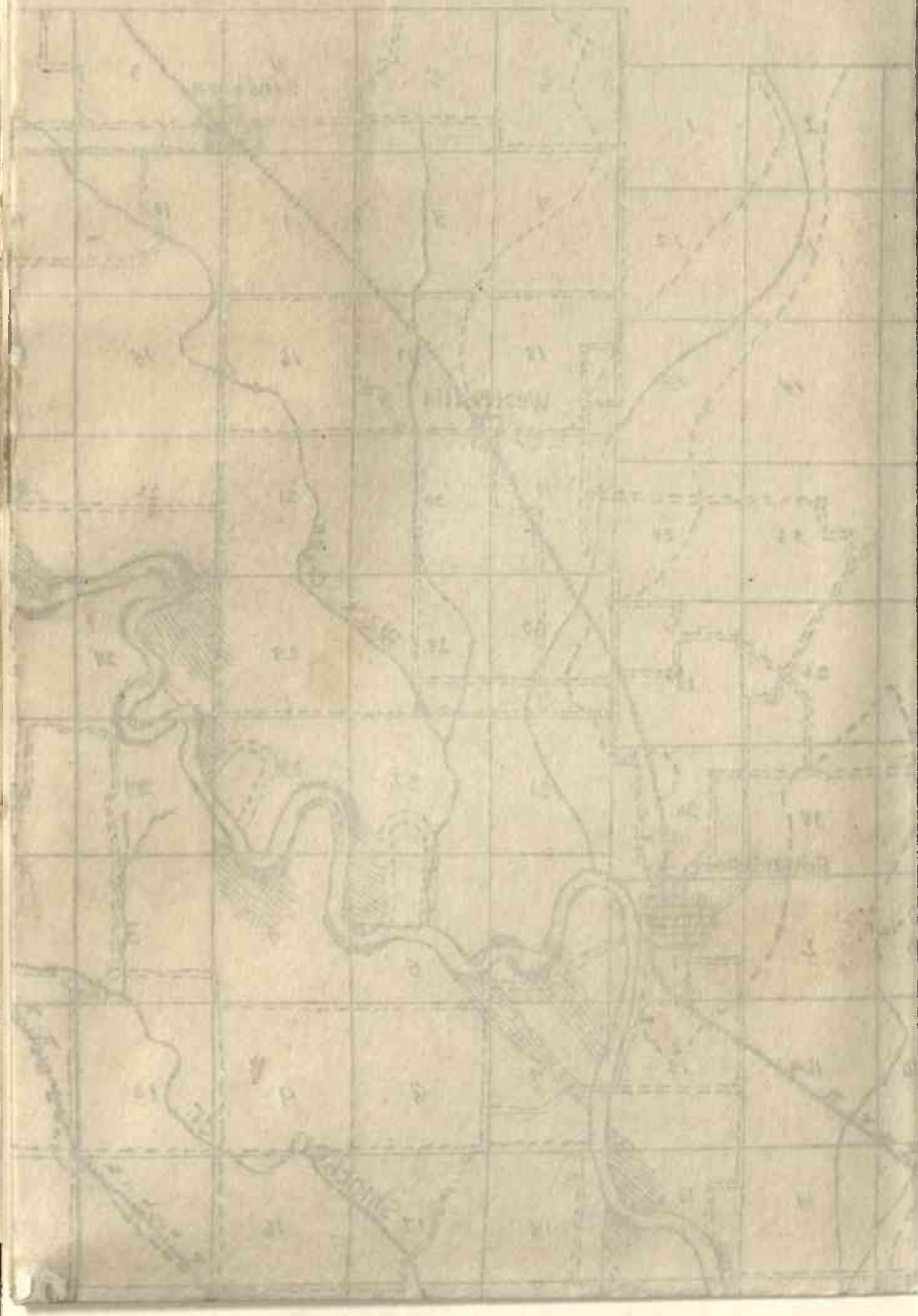


FIG. 2. A typical hole washed out by the current. One mile south of Romona.



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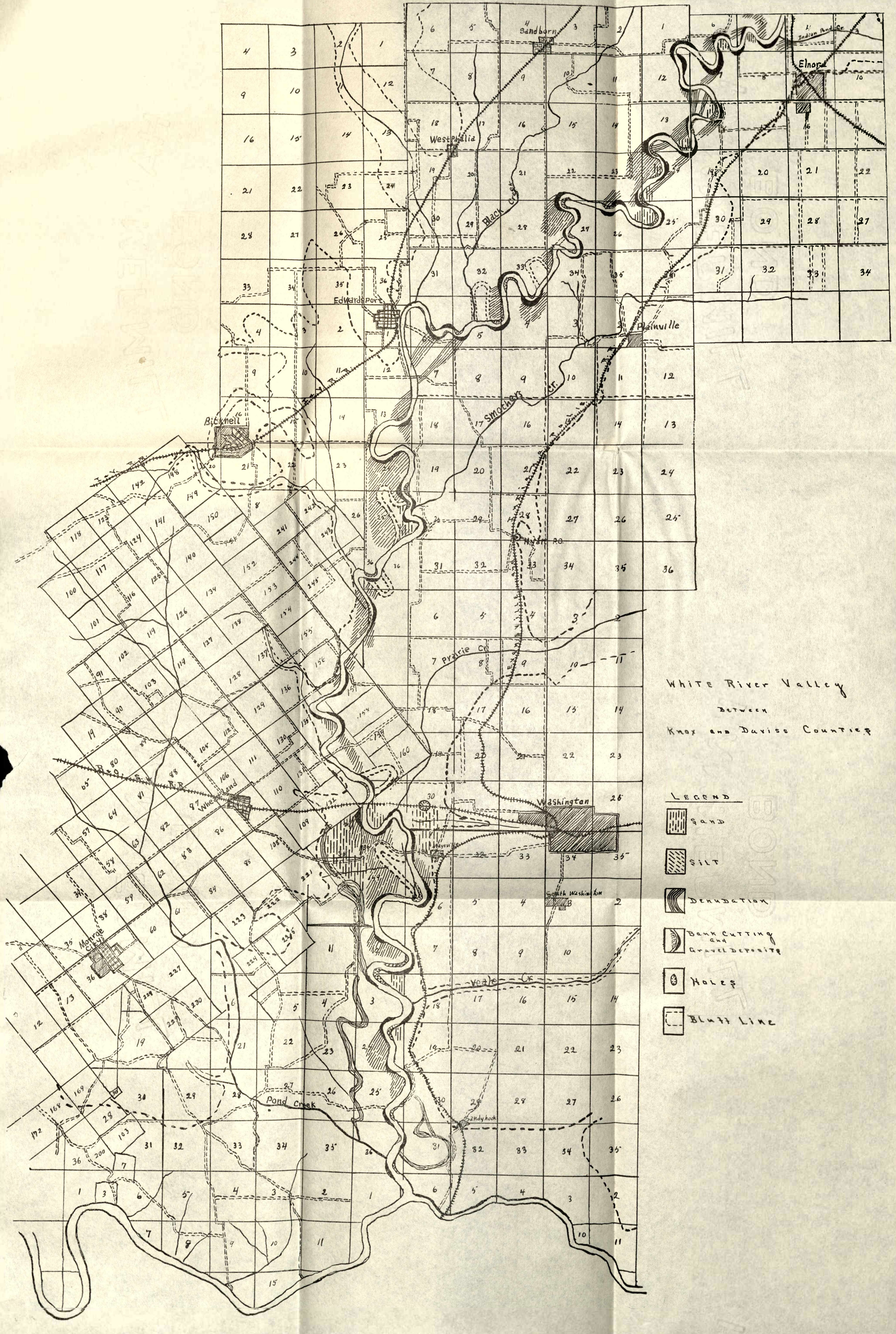
White River Valley
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Edwardsport
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Plainville
Black Creek
Smothers Cr.
Prairie Cr.
Washington
Wheatland
Monroe City
South Washington
Veale Cr.
Pond Creek

valley. The plate indicates the part of the B. & O. track and grade that was removed. (See also Figs. 35 to 40.) There is no doubt that the railroad grade at this place should be partly replaced with trestle-work. On the west side of the river not only the railroad grade but the street that connects West Shoals with East Shoals served as an obstruction for the water. The cement sidewalk was torn away, but neither of the grades was badly injured. The great bulk of the water went around to the east of the town and came into the river again near where Beaver Creek enters the channel. In all, forty-four houses were either removed from their foundations or carried away. This would have resulted regardless of the railroad grade, the houses themselves being situated on the flood plain within reach of high waters.

Conclusion. The consideration of the levees along both forks of White River brings out the fact that during the March flood all of the levees brought disaster. Not only were they damaged themselves but they caused the adjacent territory to be washed and denuded, in many cases very badly. Now, since this was true in the recent flood, it will be true of future floods that approximate the recent one. We are now ready for the pertinent question: Is it worth while to provide protection against such floods in the future? We will presume that the above question is answered in the affirmative, just for the sake of showing how simply and practically protection may be provided in regard to railroads and public road embankments. From a study of the conditions as they are briefly given above, the following conclusions present themselves:

1. Railroad embankments have almost invariably impeded the free passage of the water and caused it to be ponded above for a time.
2. Railroad embankments suffered severely and in some cases bridges were destroyed.
3. By the breaking of the embankment, the land below has been greatly damaged and in some cases injured beyond reclamation.
4. A noticeable lack of trestle-work was the cause of the water being impeded and ponded.
5. Near Riverside, Greene County, the C. T. H. & S. E. R. R. had plenty of trestle-work and no serious damage was done, either to the embankment or to the land immediately below.
6. The I. C. R. R. at Bloomfield was only slightly damaged because of the long stretch of trestle-work that permitted the water to pass unimpeded.

FIG. 36. Mill Street, West Shoals, looking south.

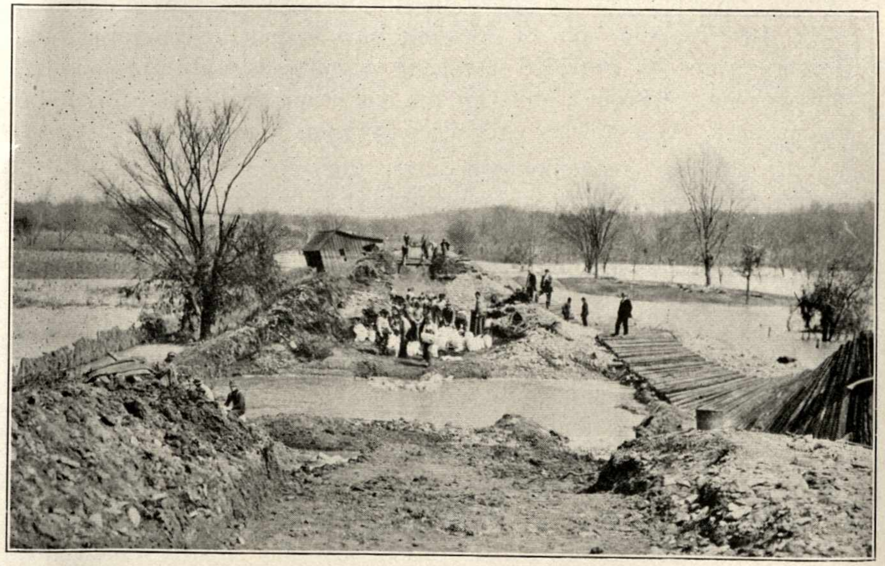

FIG. 37. B. & O. grade, east of Shoals, after the flood.

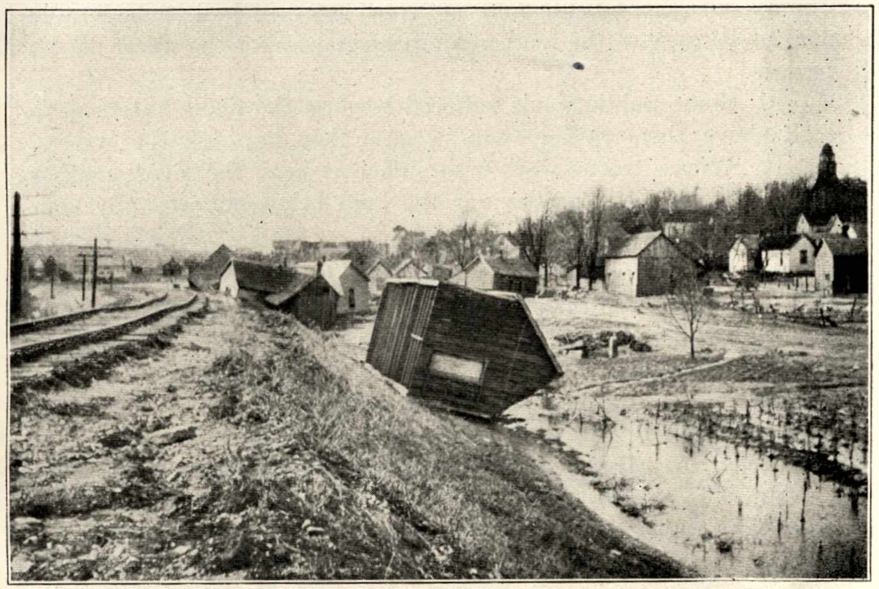

FIG. 38. B. & O. grade between East and West Shoals. Note crooked track.

FIG. 39. Water flowing over railroad grade between bridge and West Shoals.

7. Public road grades, such as at Henderson Bridge in Morgan County, at Bloomfield, and at Newberry suffered considerable damage because of the inadequate passage-way for the water at the bridges.

8. Some public roads suffered because the flood waters were high above them rather than because they impeded the waters.

9. Where trestle-work was sufficient near the river, neither the bridges nor the grades nor the land below suffered any considerable damage.

From these conclusions, it seems that the way to prevent damage by future floods, so far as railroads and public road embankments are concerned, would be to provide more trestle-work. This remedy is both simple and practical.

The levee question along White River above the junction of the two forks is but little related to such a question in a great valley like the Mississippi River Valley. In the Mississippi valley the object in view is to keep the great volume of water that comes from the upper tributaries confined to a relatively narrow channel, and to keep it from spreading over the entire valley, or at least any considerable portion of it. Along White River the object in view is to protect small areas from currents which would wash and carry away the top soil. In many cases it is not desirable that the water should be kept off the land, as back water generally enriches the land with its deposit of silt. However, the levee question along White River is related to the lower Mississippi River problem in the fact that White River is a tributary to the Mississippi River, and the rate of discharge, etc., all have an appreciable effect upon the lower course. For instance, should all of the tributaries be improved before the lower course of the river was improved, serious consequences would follow. Local improvement only tends to make the damage more intense farther down the course. The levee situation on White River has little in common with the levee situation of the lower Mississippi River, but there must be some co-operation in the plans of the improvement of the two different parts of the same river system. Improvement should begin at the lower course and be extended toward the tributaries.

The levees which were encountered during the flood investigation were all built with the idea of protecting a small area of land, and they were all wisely planned for that purpose. These levees served well in ordinary overflows. In the March flood they were all failures. They were not strong enough to withstand the pres-

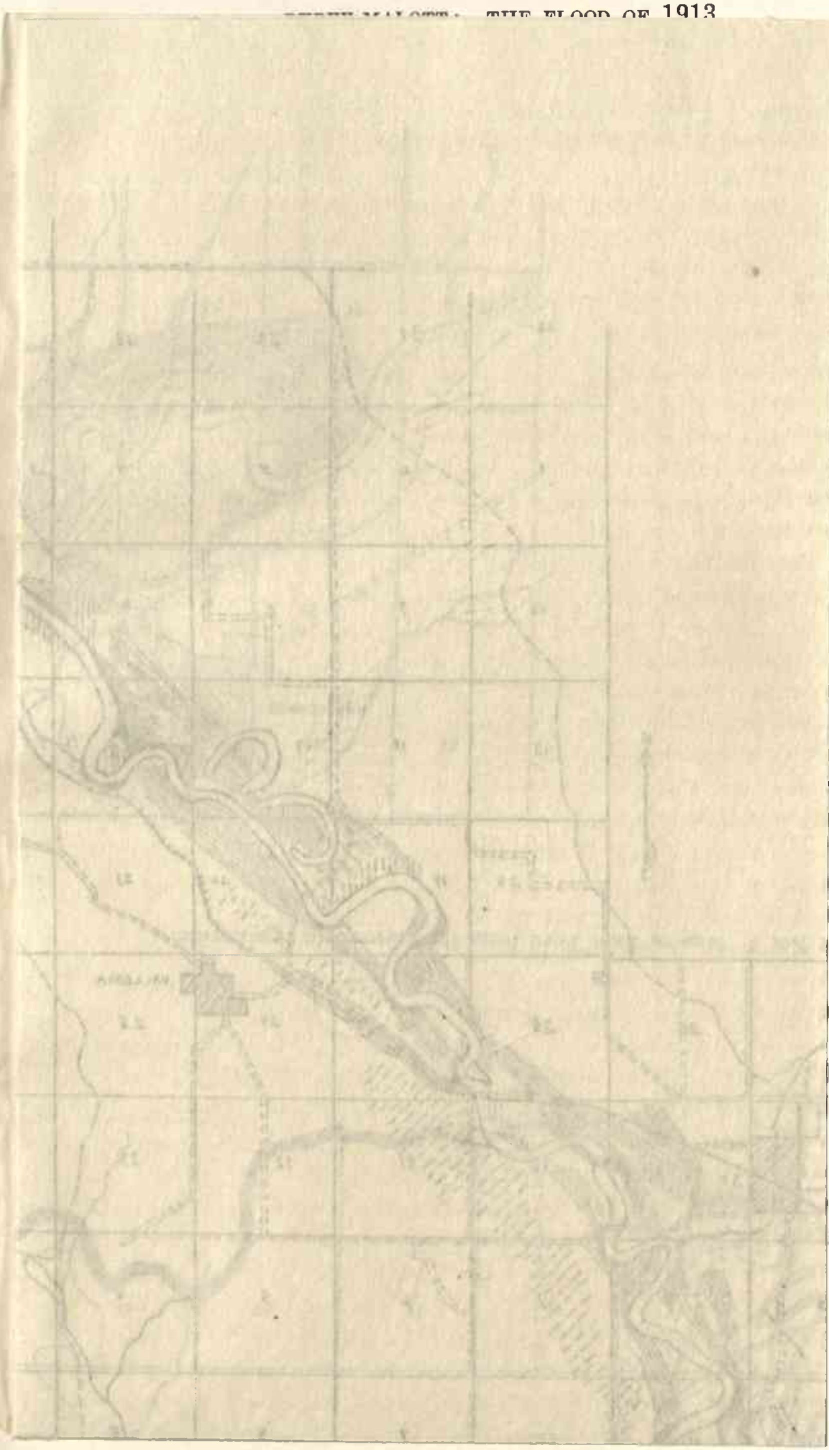

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CHART No. 7 Map of East Fork from Brownstown to Sparksville.

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sure of the water, or were not high enough. Would it be practical to construct levees both strong and high enough to protect the land from floods of the proportions of the recent one?

The writers believe that it would be practical to construct levees of such a nature. Several of the levees considered were high enough, but were weak in places. In most cases it would be well to have them higher. A levee is like a chain; it is no stronger than its weakest link. The weak places should be strengthened. The most dangerous enemies to the levees seemed to be the ground-hogs. In very few cases do the levees need to be protected with a rock covering, but it would be well to have trees and shrubs growing on them. The levees considered in this paper were effective for years before the 1913 flood, and would have been effective then if they had been a little higher and a little stronger in a few places where they were subject to unusual strain. The extra expense in making them flood proof would be nominal, and if they are to be used at all they should be made strong, for a weak levee causes much damage when it breaks.

There are many places along White River which could be protected by levees. Even in many of the narrower confines of the valley, levees could be made with much benefit to the land. For instance, along the East Fork of White River the valley itself is continually turning to the right and to the left and the river crosses from side to side in its tendency to be always on the outside of the turn. Where it leaves a bluff on one side to cross to a bluff on the other side, the river bank is usually low; sometimes there is no bank at all, and a low strip of land continues to 'B,' on to 'C,' but usually it is much lower at 'A' and 'B' than it is at 'C,' where the current enters the river channel. The current flows in this low strip whenever there is even a minor flood. A levee placed at 'A' would be hard to hold, but one placed at 'B' would not be so likely to be washed away since the current from the river channel would not strike it. A levee placed at 'B' would need to be very little higher than the valley land near the river where it is usually highest. Such a levee would in time cause the low strip to fill with silt and would be a great improvement to the land. The low area to the leeward of the levee would probably become a pond or be very wet, but this condition could be overcome by tiling.

FIG. 40. Railroad bridge at Shoals.

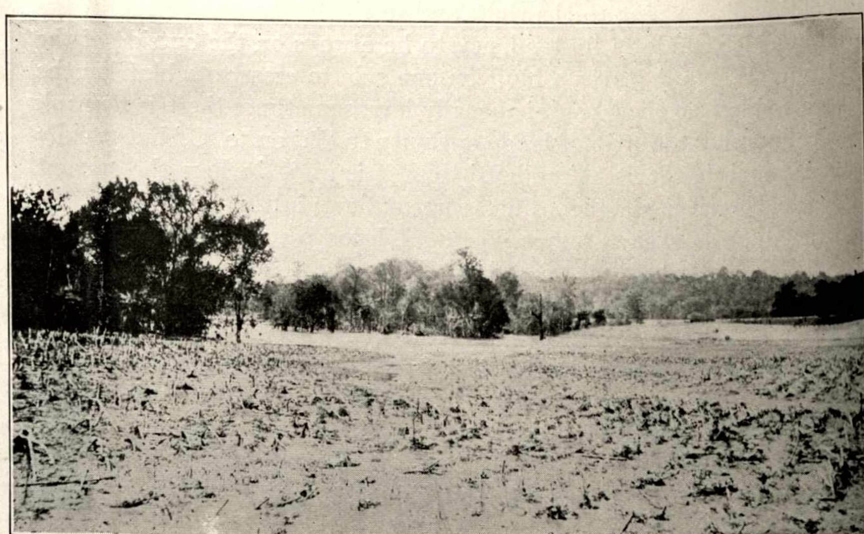

FIG. 41. Water ponded in little stream about Southern Indiana Power Company's dam at Williams.

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Valley of East Fork of White River in Lawrence County.

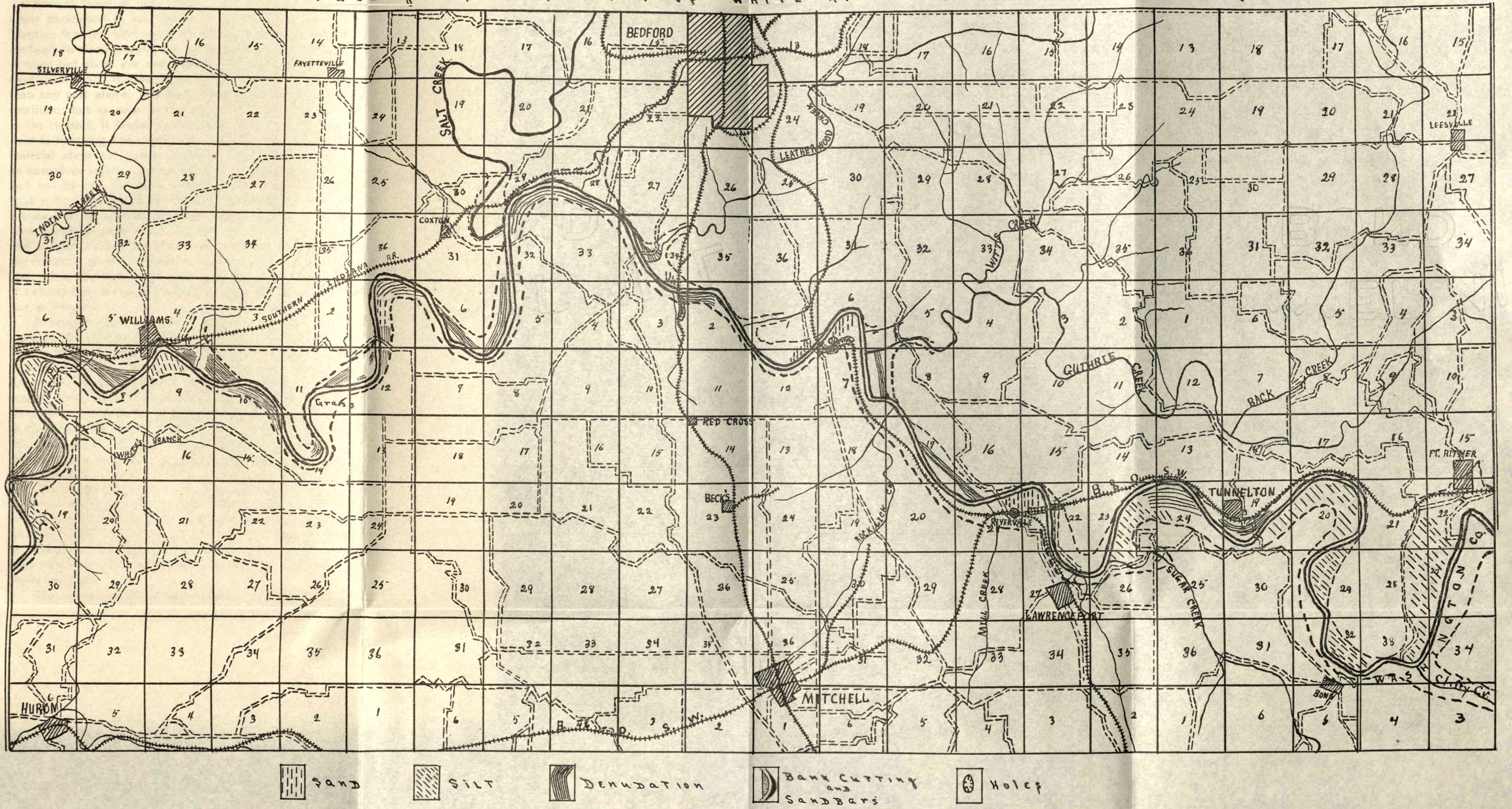
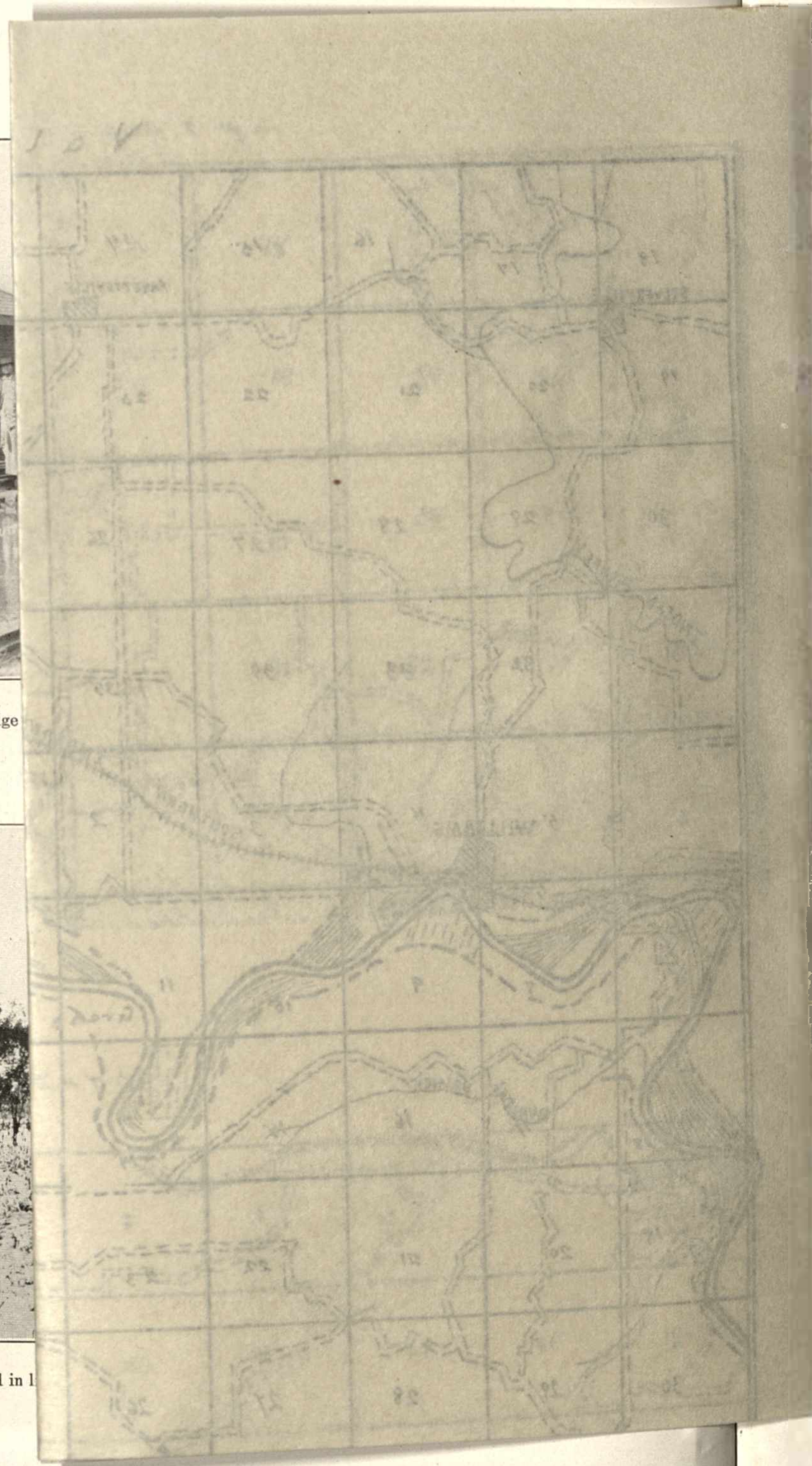


CHART No. 7. Map of East Fork from Ft. Ritner to a place five miles southwest of Williams.

Fig. 40. Railroad bridge



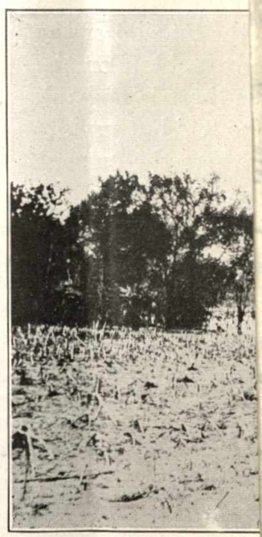


Fig. 41. Water ponded in l

Bank-Cutting

Several times in this report, bank cutting has been particularly mentioned as an important phase of the flood situation. Mention has also been made of the fact that bank-cutting is not confined to flood stages, but to stages when the water is three or more feet above low water mark. As a rule, the bottom of the river channel and the lower part of the banks is somewhat tougher than any part above. No bank cutting goes on in the low water condition; but as soon as the water has risen three or four feet in the channel, it begins to come against the outside bank of the river in rounding a meander, and comes in contact with the looser material above the tough, compact, lower part. Caving is then an immediate result. As the water rises higher, it gains in velocity and its efficiency for bank cutting increases until the channel is bank full. This is probably the most favorable condition for bank-cutting, for, as soon as the water begins to flow over the valley land, across the neck of the meander, some of the force of the current is taken in the direction of the overflow, and the velocity of the current is checked, thereby lessening the cutting power. Moreover, when the water rises high over the valley land, the thread of swiftest flow is raised, perhaps, above the banks and bank-cutting is lessened.

It is interesting to note the relation of the height of the river banks to the width of the valley. On the West Fork above Gosport and on the East Fork above Sparksville, the valleys are from one to four miles wide, due to the very susceptible erosiveness of the Knobstone Group of Rocks. In these regions the banks are low, ranging from six to twelve feet above low water mark. From Gosport to Worthington, on the West Fork, and from Sparksville to the southwestern corner of Martin County, on the East Fork, the valleys range from less than a quarter of a mile to a mile in width, due to the highly resistant erosiveness of the Upper Mississippian rocks and the Mansfield sandstone of the Lower Pennsylvanian rocks. The banks in these regions are from twelve to forty feet above low water mark. The remaining parts of both forks are in the easily eroded coal measures, and the valleys are, therefore, wide. Again, the banks are low, ranging from eight to fifteen feet in height. Thus, in the wide valley regions, the river banks are low, and in the restricted valley regions the river banks are high.

The above conditions and relations are easily explained. In

the wide valley region, the streams meander about in the wide alluvial expanse, continually cutting on the outside of the meanders and shifting the channel of the stream constantly. This constant shifting or changing of the river channel gives no time for the incision of the stream bed, or for the building up of natural levees along the banks. This shallowness of the channel keeps the stream in the easily moved sand and gravel underlying the sandy soil of the surface, and does not permit it to have the tougher, compact material for its banks. Such conditions favor bank-cutting and meandering. Should the stream have time to cut down into the more resistant material, it is likely that the bank-cutting would be less. The alluvial material of the valley however is deep, since the valley is a filled valley; probably seventy-five feet in depth below the present river channel.

In the narrow valley regions, the channel does less meandering and especially in the East Fork region, where there is little or none. Consequently, it has remained in its present channel for a very long time, and has cut down into the more resistant material. Trees have grown along the banks and natural levees have been made. The channel, therefore, is deep. Perhaps the most important factor in keeping the channel constant is the narrow winding valley itself. The valley in these restricted regions is a great intrenched meandering gorge. The channel crosses from one side of the valley to the other, always keeping its outside bend against a precipitous limestone or sandstone cliff, with the valley always on the inside of the bend. This condition exists because of the winding valley itself. It is impossible for further meandering to take place, because the outside of the bends is always against a rocky cliff generally over a hundred feet in height. This is sufficient to explain the much greater depth in the constricted regions of the White River valleys.

Before considering the details of bank cutting along White River, something should be said about the need of the preservation of the land affected and the loss to society in general because of the consequent loss in production. If the present rate of increase in population continues, there will be 200,000,000 people in the United States by the year 1950. When we stop to consider what it means to produce twice as much as we are producing now, we are constrained to think of vast numbers of acres called into use which are not at present available. As the population increases, more and more food is needed; but the subsistence space does not increase. It is even made less, for actual room is used

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Chart No. 8. Extending from Chart 7 down East Fork to Loogootee.

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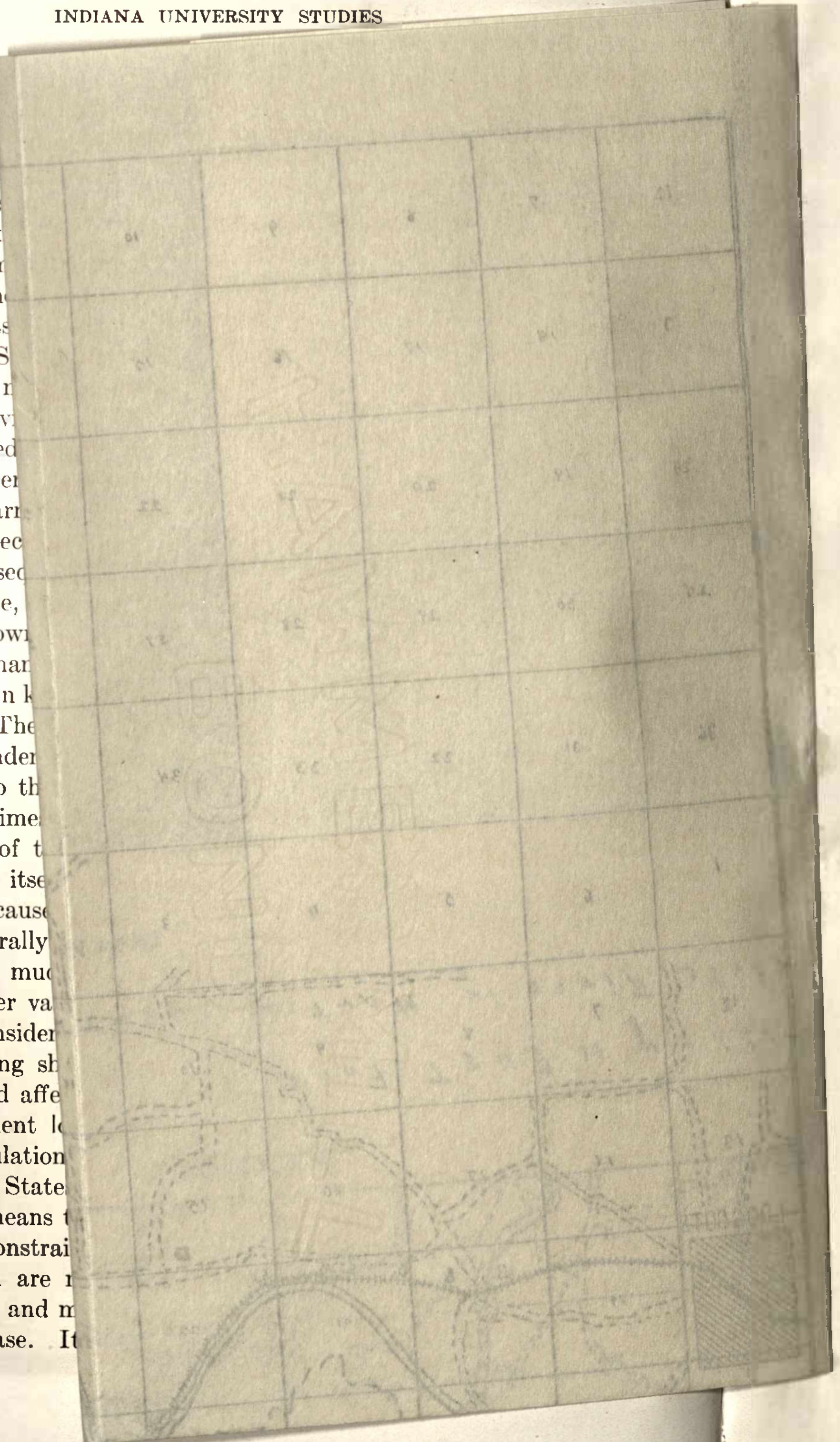

which might otherwise be areas of production. Since the subsistence space never becomes greater, the land that is not now practical for production is the land that is the most desirable. Valley lands with their deep alluvial material are, as a rule, fertile. They form the cream of the land. For ages the rich soils formed on the uplands by decaying vegetation and animal life have gradually accumulated in the valley lands. The vast fertile stretches of the Mississippi valley, one of the greatest and most fertile areas in the world, are perhaps the greatest asset that the American people have. Yet there are thousands of acres lying in idleness, waiting for the time to come when the population has so increased that these areas will be demanded for subsistence space. The time is coming near; already the clamor is heard in the numerous schemes and plans for making this land available for production.

Let us see what it means for an acre of land to be lost by bank-cutting and caving. It is true that land thus cut out by the waters is not absolutely lost, but it is unavailable for at least ten years, and probably twenty years. All figuring, however, is done on the least number of years; but it is to be understood that double the loss due to the lack of production may be figured, and the result be as nearly correct. The coarse material cut from the outside of the meander is carried across the stream by cross currents and deposited on the lower and inner side of the meander. The finer material is carried on in suspension, and usually the most of it is deposited as silt over the valley land where the waters are relatively quiet. The sand and gravel bar thus made on the lower inner side of the meander grows larger each year, and gradually vegetation grows upon it. This vegetation, though scanty at first, is an important factor in causing silt to lodge, and gradually the bar is built up with a layer of fertile silt or soil on top. But it takes at least ten years, or probably twenty, for this to take place. Our acre of land has been lost for ten years at least. During this time it could have been producing sixty bushels of corn yearly. At fifty cents a bushel this could have brought thirty dollars. In ten years three hundred dollars have been lost to society, plus the seventy-five dollars that the acre of land itself would bring at present. In figuring this, one of the cheapest crops has been used; but it is a crop that is now practical for such acres as are now being lost annually along White River. If the figures were for one of the more intensive crops, they would show a loss running into the thousands. The time is coming when the loss will be so calculated.

Bank-cutting is not much of a problem in the constricted val-

ley regions, and especially so in the constricted region of the East Fork, since the channel does little or no meandering except to follow the intrenched meanders themselves. Considerable bank-cutting occurred, however, in the constricted region of the West Fork. This will be explained later. When in flood stage, the water tends to go directly across the valley next to the sloping bluff, rather than follow the channel across to the other side and sweep around the cliff on the outside of the intrenched meander. (See Diagram 2.) The position where the water leaves the channel ('A' in Diagram 2) is usually low, and sometimes considerable bank-cutting is done. A typical instance of this kind occured in Owen County above Spencer, a short distance below the mouth of McCormick's Creek. Despite the fact that trees were growing here, and that ballast had been hauled and dumped at the place, much cutting was done. But such places in themselves are rather insignificant in comparision to the wash below them, and the bank-cutting in the meanders as found in the wider portions of the valley.

It is understood that in the wide valley regions of both forks of White River, the outside of nearly every meander is growing larger each year, and fertile soil is being undermined and carried away. To call attention to every meander in these regions is not the purpose of this report. A few typical illustrations will be chosen and sufficient detail given to enable the reader to understand the situation. Constant attention must be given to the charts.

In Morgan County from near Martinsville, to the vicinity of Little Indian Creek below, there is a stretch of about five miles of river which is relatively straight. (See Chart No. 2.) Damage done to this region was relatively slight except that due to bank-cutting. Attention is called to this section of the river because as yet the meandering is incipient. The ones started will become larger and larger as time goes on, and in a few years they will be relatively large. The damage done then will be many times what was done in the recent flood. The first bank-cutting in this stretch of the river occurred in the slight bend just north of the Vandalia Railroad bridge. A strip of land from forty to sixty feet wide and twenty rods long was taken away. This only accentuates the bend here. If nothing is done to prevent the cutting here, the cutting will continue year after year, making the bend larger and farther down stream, until the grade and abutment of the railroad bridge will be threatened, having come within the scope of the enlarging meander.

Between the railroad bridge and a small creek coming in from

the west, the current cut across as indicated in Plate No. 2, and made waste land of about five acres. Some of this was badly cut, while the remainder was covered over with coarse gravel. The current of the bank-full stream was deflected to the other side of the river where it cut considerably into Mr. Rutledge's land. He lost perhaps a half acre of good soil. There is no doubt that this meander will continue to grow until it has united with the one below the place where the stream enters the river. Such a meander in the course of a few years will destroy several acres of land on the east side of the river.

In the southwest corner of Section 12, about one-fourth acre was lost by bank-cutting. About as much was lost in Section 14 on the same side of the river. These two places are typical incipient meanders; as yet they are small, but, as is the case with all meanders, they will grow larger each year. It was said that the lower one was started by a charge of dynamite being exploded near the right bank in an endeavor to kill fish. Anything that deflects the current against the bank will start a meander. Cases were noted in which logs and other debris were so lodged as to deflect the current sufficiently to start a meander.

Southwest of Paragon is a stretch of river in which great damage was done by bank-cutting. Chart No. 2 shows the extreme crookedness of the river at this place. This extreme meandering will never correct itself. Although cut-offs may be made frequently, they are never made in nature with any degree of permanency, because of the little crooks left which immediately develop into new meanders. This place shows that a cut-off was made recently which partially corrected the most extreme meander, but another is already begun which in a few years will be as bad. As a result of this constant meandering, a great tract of the land here, which ought to be worth one hundred and twenty-five dollars an acre, is either a sandy or a swampy waste.

The particular damage due to bank cutting alone is as follows: In Section 22 opposite the large island, one acre was lost. In rounding the next meander on the left side of the river, three acres were cut from the bank. Opposite this cut is a bare gravel bar of about six acres. Directly north of this on the right bank in Section 16, three more acres were carried away. Opposite this cut is a gravel bar of about four acres. Three acres were also lost in the succeeding meander on the right bank just before reaching Burkhart Creek. Opposite is a gravel bar of about five acres. The next loss is below Burkhart Creek; it also consists of about

three acres. The bar opposite this cut is at least ten acres in extent, all of which is entirely bare of vegetation, showing that it has been made within the past two years. Immediately below this great bar the current of the channel has made another cut of about three acres. This is the last meander in this remarkable series. Thus during the last flood sixteen acres were lost within an air line distance of two miles. This means a loss of something like two thousand dollars for the land alone, to say nothing of the accumulating crop loss for the minimum ten years.

The region is very susceptible to bank-cutting on account of being composed of loose gravel with about three feet of sandy soil on top. This condition, however, is favorable for the correction of the river channel here. It could be easily dredged out in any attempt to straighten the channel. The great loss constantly occurring in this region could be done away with, with less cost than that occasioned by the 1913 flood alone. Less than two miles of dredging would take the channel in a straight line from where it comes against the bluff in Section 22 to the straight stretch of the channel which leads toward the bridge in Section 20. It would take less than two miles on account of part of the old channel itself being within the straight line, and, therefore, able to serve. Undoubtedly this stretch of valuable valley land cannot be abandoned to the ravages of such profligate meanders as now occur, for very long in the future. Practically five hundred acres are unfit for use. With the river corrected, and taken care of when once corrected, these five hundred acres of practically worthless land would be worth one hundred and twenty-five dollars an acre in a very short time, to say nothing of the value to society in general of the amount such land might produce. A cost of two thousand dollars and a small annual outlay for taking care of incipient meanders would bring this practically worthless area to a selling value of $62,500 in a very short time.

For four or five miles below Paragon the river is relatively straight, having only a few incipient meanders that should be stopped by all means. The damage done here was slight. Not over twelve acres were denuded, while much of the region was silted, enhancing its value considerably.

The region below Limestone Creek to the vicinity of Romona must be mentioned in this report. It is a region of meanders which are past the incipient stage. They are likely to become still larger, but the damage they are doing now approaches the maximum. The first two little cuts (see Chart No. 3), one on each

side of the river, are incipient, and the damage done by them in the flood was slight. They deserve attention only for what they are capable of becoming. These little things neglected are the things that sometimes become alarming because of what they develop into.

In making the bend in the northern part of Section 2, the river has cut away as much as five acres in the past year. This land belongs to Mr. Benj. Gray. Mr. Gray, however, has gained as much land as he lost, by the river turning in the other direction below. The amount gained is a great bar as yet, and not equivalent in value to that lost. A cut-off was almost consummated, reaching from the bank cutting on Mr. Gray's land to the next meander which turns to the northwest and leads into Section 3. If this cut-off should take place, it would at least eliminate one meander, which would be all the better, although Mr. Gray would be a heavy loser. The meander which leads into Section 3, cut about three acres from the bank during the flood, but about twenty acres have been lost within the last ten years. A great sand and gravel bar lies on the inside of each of these meanders, each consisting of several acres, testifying to the waste land that a meandering stream can make. Without considering the two bank cuts below (just east of Romona) in which about three acres were lost, and the ten acres which were literally devastated by the over-running current nearby, the conditions call loudly for attention. The river could be straightened here, even in this bend of the valley, in such a manner as to eliminate the meanders. Although the valley is narrow, in the long run it would be much better for all concerned if something was done toward the end mentioned. Mr. Gray expressed his willingness to have this done if proper adjustments could be made. It appeals to reason that when sixteen acres are lost within one year, and within the past the conditions have been such that over one hundred fifty acres have been turned into a mere waste, some constructive measures should be taken.

In Owen County there are two or three places that might be given attention, for instance just below Spencer and just east of Freedom; but as a whole the valley is narrow and it would be more or less expensive to straighten the channel, even in these places. There is no doubt, however, but that conditions could be bettered, and with little expense damage done by bank cutting and denudation could be greatly mitigated.

A glance at Chart No. 4 shows that bank cutting in Greene County was very severe. It can be distinctly noticed that the

bank-cutting is in those stretches of river valley where the river has meandered extensively. The vicinity of Worthington is striking for its meanders. The large irregular loop to the north, one and one-half miles east of Worthington, is certainly needless and could be corrected with a small outlay in comparison to the value of the land it would redeem. But it is the series of long loops parallel to each other south of Worthington which attract most attention. In these long parallel loops eighteen acres of land was lost by bank-cutting, and over one hundred acres so cut and denuded that it cannot be used for farm land for many years to come. This is speaking of the damage done during the flood alone. Less than one and one-fourth miles of actual dredging would remove every one of these loops. The stream actually travels four miles to get one and one-fourth miles. If this straightening were done, there would be a long stretch of river from Worthington to near Bloomfield with the exception of one meander in Section 9, three miles northwest of Bloomfield. The meander which reaches westward in Section 33 comes against a sandstone cliff, and consequently no cutting occurred in rounding it. At this point the stream passes over sandstone in a series of rapids known as 'Rocky Ripple.' Another noticeable feature of this series of meanders is the remarkable width of the channel. It ranges from thirty to sixty rods in width.

Attention has already been called to the remarkable loop just below Bloomfield. There was but little land lost at this place; perhaps not over an acre in actual bank-cutting was carried away, but the loop itself has caused considerable land to be practically worthless. The neck of the meander is badly cut and denuded; it was cut more the year preceding the flood than during the flood. The short distance across the neck of this meander and the presence of the cliff on the left bank where the water would come against it in case a cut-off were made, present a practical situation where a cut-off could be made, thus eliminating a meander at little cost, much to the advantage of all concerned.

Chart No. 5, shows the conditions of the river between Knox and Daviess counties. As stated before, the river between these counties is practically a continuous series of meanders, beginning in the southern part of Greene County and ending at the junction with the East Fork. The details of no particular place will be given here, but special attention is called to the upper part of Chart No. 5. It would seem that cut-offs are incipient in many places, yet not a single one was made during the flood. Two were found which had been made within the past few years, but two other places were found in which the river, having made a cut-off several years before, had reverted back to its old meander again. One of these latter places is just west of Elnora, and the other is about four miles above Edwardsport.

A fairly accurate estimate of the aggregate number of acres lost by bank cutting between these two counties during the year is seventy-five acres. Hundreds of acres are lying in idle sandy and swampy tracts within the inside bends of the numerous meanders. No fair estimate of less than twelve hundred acres could be made, entirely due to bank cutting, which has accumulated from past years. This land cannot be reclaimed short of straightening the channel, nor can the continued bank-cutting be stopped or mitigated with anything less. As yet this paper cannot do more than call attention to this phase of loss to society in general; but as has been intimated before, a loss of something like $300,000 in ten years between these two counties must be considered in the near future.

Of that part of the East Fork traversed, the only bank-cutting amounting to any considerable damage was found in Jackson County. (See Chart No. 7.) Even here it was not severe. From Brownstown to Sparksville, the only part of the East Fork in the extensive valley coming within the notice of the writers, there were not over twelve acres lost by bank-cutting. The channel from above Brownstown to near Medora is relatively straight except for two rather large meanders. Consultation of the chart will show that these could be remedied with comparative ease. The one between Brownstown and Vallonia almost effected a cut-off during the flood, yet there would necessarily be considerable dredging before the channel could be straightened at this point. The other meander, opposite Vallonia, would require considerable more dredging for its elimination.

Below Medora several meanders are well started, which will continue to grow larger; considerable damage by bank-cutting may be expected from these in the future. Between the junction of the Muscatatuck with White River and Sparksville, a series of remarkable meanders occurs. Considerable bank-cutting was done here, with the exception of the backward turning loop from Section 17 to 16, known as the 'Devil's Elbow.' At this place the river runs into the bluff, and, of course, can do no bank-cutting. There are places across this series of meanders where the river might be crossed three times within a distance of a little over a quarter of a mile.

Charts Nos. 8 and 9 show the river in the restricted valley

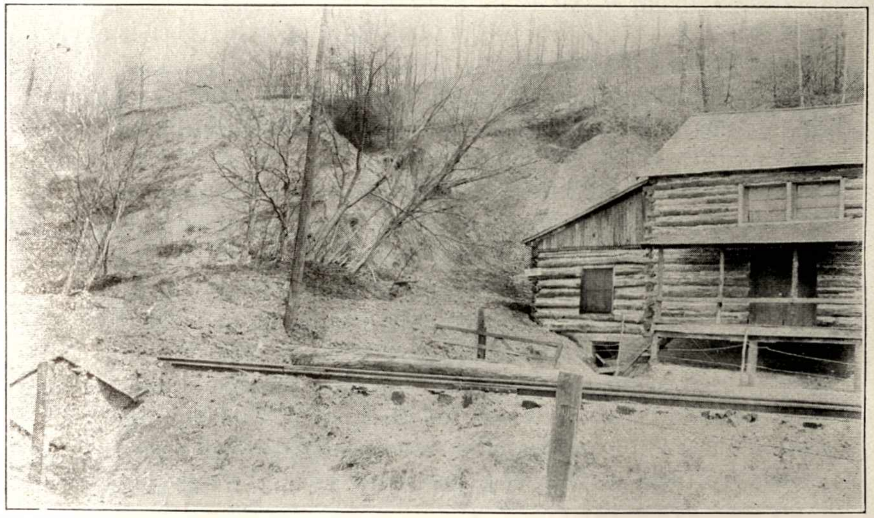

Fig. 42. Landslide that obstructed interurban and public roads, three and a half miles north of Martinsville.

Fig. 43. Landslide, Martin County.

region in which no bank-cutting occurred. In this region but little damage was done except that done to improvements and by denudation. As to improvements, there are but few to be mentioned outside of what were taken up in connection with levees and embankments. The steel bridge at Rivervale was destroyed, as shown in Figure 34. The dam across the river at Williams aroused much speculation in the minds of the writers as to its probable effect; but on careful investigation, absolutely no damage could be traced to it as a causative agent. It does, however, cause the water to be ponded as far back as the pumping station at Bedford, thereby making the banks lower than they were before. This will cause overflows to be rather imminent in the lower ponded region. The water even at low water mark, is ponded in the little streams which enter the river. This is well illustrated by the little stream coming in from the north just above Williams. (See Figure 41.)

It has been noticed that bank-cutting occurred in the constricted valley region of the West Fork, yet with much less intensity than in the wide valley regions. But it is a striking fact that none occurred in the constricted region of the East Fork. Why should it occur on the West Fork and not occur on the East Fork in similar valley conditions? Primarily, it is because of the intrenched meanders, and the stream's nice adjustment to them. The stream sweeps in great curves, just as the valley itself meanders, and keeps its outside bank a constant cliff which is not noticeably affected. In the West Fork region, the intrenched meanders are more or less irregular and broken and the stream is only rarely adjusted to them. The channel, therefore, meanders about over its narrow flood plain, doing considerable bank-cutting. A study of Charts Nos. 4 and 8, will verify the above statements.

Of that part of White River valley traversed in the investigation of the flood conditions, an aggregate of one hundred sixty acres was lost by bank-cutting. This total is fairly accurate. Figuring at the low price of seventy-five dollars an acre, $12,000 were lost in land. The value of these one hundred sixty acres for the ten years lost to the State would be $48,000. This makes a total of $60,000. Since bank-cutting is relatively the same each year, on account of its taking place under any condition above low water mark, it might be estimated that ten times (twenty times is perhaps nearer correct) this loss is continually placed upon society on account of bank-cutting. This would make a total of $600,000. From the proportion of the amount of water carried by other streams, ignoring the minor streams, to that of White River, (the part in-

vestigated), their proportionate length, and counting bank-cutting as one-half as much in the northern part of the State, on account of the relative ability of the soil of the glacial region to withstand bank-cutting, a fairly accurate estimate of the total bank-cutting of the entire State during the flood of 1913, would be eight hundred fifty acres. This is not counting the Ohio River at all. The estimate in land loss for the State would be $63,750. The loss to society because of lack of production for the minimum ten years would be $255,000. The total loss, then, for the year of the flood would be $318,750. The total loss to society for the entire State (figuring the loss as accumulating for the minimum ten years) would be $3,185,500. But this total estimate is far too low. This is figured on a total ten-year loss due to bank-cutting of 8,500 acres, which is probably fairly accurate, but there is far more land than that lying idle due to bank-cutting. It was estimated that at least 1,200 acres were idle due to bank cutting between Daviess County and Knox County alone. It is evident, then, that the total estimate is far too low; an estimate of from two to five times the amount would be more nearly correct.

Now, since sufficient details concerning bank-cutting along White River have been given to get a grasp of the situation, and since some idea of the immediate and cumulative loss is before us, let us consider what might be done either in stopping such a loss, or in mitigating it. The writers are not of the opinion that the entire river channel should be straightened nor any large part of it, but they do think it not only feasible, but advisable to straighten certain portions of it, as has been brought out in the above discussion. Many farmers who own land in the valley were consulted, and the majority were of the opinion that the river channel could be profitably straightened in many places. They think that the river should be improved at the expense of the people that are benefited. Their annual losses would in a very short time be enough to pay for the improvement of the channel; and if a small tax were levied on all of the landowners in the region coming within the scope of the benefit, to furnish funds to keep the banks protected where there is a tendency for them to be washed by the current, and to keep the channel free from obstructions that are liable to cause the current to be deflected against the bank, the situation would be practically within control. As has been emphasized, not only the land which is lost annually by bank cutting might be saved by preserving a straight channel, but the waste land already made by bank cutting could be redeemed. This straightening of

Fig. 44. Montgomery barn, west of Williams, showing river at highest stage.

Fig. 45. Montgomery barn, water partially subsided.

the channel would cause the velocity to be increased, which in turn would lower the channel, making it possible for it to carry more water in times of flood without overflowing the banks. A destructive flood in the growing season would cause a damage equal to the amount necessary for such improvements as mentioned above. However, destructive floods in the growing season are not the rule in the White River valley, but they are a possibility which is staring the farmers in the face all of the time, and there is no way of predicting just when the valley land will be flooded. In another place the writers have shown that the majority of the floods in the Ohio valley occur during the first four months of the year; but that does not hinder the flood waters from cutting into the banks, or washing the soil from the flood plain. One farmer pointed out the fact that in one way, at least, the floods that come the first four months are more destructive to the soil than those that come in the dry summer months. If the ground is not frozen when a flood comes during January, February, March or April, the ground is looser than it would be in the summer months, and hence more easily washed. Freezing and thawing are the causes of this looseness of the ground. In the summer months the ground is likely to be dried out and to be harder and less easily eroded. The ground that is under cultivation during the summer months, of course, will be badly washed. An overflow at any time of the year is sure to cause a large amount of damage, but by straightening the channel the increased fall will cause the current to cut the channel deeper, thus lessening the need of levees, and carrying the water off in a much shorter time.

But straightening the channel does not stop bank-cutting. It may mitigate it for a short time, but if that is all that is done, in a short time conditions would be as bad as before. As has been said, the current must not be allowed to come against the bank in such a manner as to start a meander. In a straight stretch of the river let no meanders get started. If they by some means occur, steps should immediately be taken to keep them from growing larger. Many places came under the notice of the writers where rock had been thrown along the bank to prevent further bank cutting. These banks, riprapped thus with refuse rock, were not cut in the least by the current. At other places, piling had been thrown down and brush and other debris packed in behind. Below Spencer, in a very decided meander, rock jetties had been extended out in the river some twelve or fifteen feet. Rock was also thrown on the bank to prevent the current from cutting around the jetty.

These, too, were very effective, and relatively inexpensive. Any of these methods could be reinforced by planting trees along the bank, and these after a few years would protect the bank very effectively. Sycamores and willows are undoubtedly the best trees to plant, as they both have an extensive root system and grow very rapidly. The writers are of the opinion that tree planting should go hand in hand with the above measures.

Landslides Due to Excessive Rainfall

Professor Culbertson at the Indiana Academy of Science, at Indianapolis, October 24 and 25, 1913, in his report on the flood conditions of southeastern Indiana, shows that the continued heavy rainfall caused the soil on the steeper slopes to creep and slide to a considerable extent. Landslides in White River drainage basin caused very little damage. Figure 42 shows a small landslide that occurred about four miles north of Martinsville. Here a considerable pile of earth slid down and obstructed the public road and the interurban track. As can be seen in the plate, small trees were growing in this portion of earth that slid into the public road. Whether growing trees have a tendency to cause or aid in the development of landslides by permitting the water to penetrate into the ground more easily, the writers are not able to say. It seems that trees with extensive roots would help to hold the soil from slipping.

Figure 43 shows where the soil has slid on a steep Knobstone hill, in the same locality. This particular part of the hill was free from trees. Other parts of the hillside that were steeper but upon which trees were growing were free from landslides. On the whole, it seems that it would be better to permit forests to grow on the steeper hillsides, especially those that are too steep to farm; for a removal of the trees will surely help along erosion. In neither of the above cases were there more than very small trees and shrubs to protect the soil.

Shortening of the Course of Bean Blossom Creek

Bean Blossom Creek flows into the West Fork of White River below the Monon Railroad bridge at Gosport. It is of minor importance, but it is interesting to note that the course of this creek will be shortened by at least 500 feet in the near future. By looking at Chart No. 3, the relation of the creek to White River

is seen at a glance. At present there are some 15 or 18 feet of land between the waters of the two streams, 500 feet above the present mouth of Bean Blossom.

Reconstructional Measures and Their Cost

The investigation of the flood results, in itself, gave only an idea of the amount of damage done, with a bare guess as to the probable cost of replacing the structures damaged or entirely destroyed. Accordingly, a little more than a year after the flood a second investigation was made with the end in view of ascertaining the cost to the counties concerned of reconstructing and repairing roads and bridges, the cost to the towns due to flood damage, and the cost to the railroads in rebuilding impaired or destroyed structures. It must be understood that this investigation could not bring the exact costs or expenses incurred by the different bodies, due to the flood alone, to an exact total, because more or less repair work would have been done regardless of the flood; because all the reconstruction work is not yet complete; and because only rough estimates could be procured on a greater part of the work. No attempt was made to ascertain some of the greatest losses, such as those occurring to individuals personally, and to corporations, including loss in traffic to railroads, and losses due to idleness of factories on account of the lack of material, etc. The figures given refer strictly to objective measures. The detailed conditions of practically all of the embankments and bridges are given in the discussion of levees and embankments and will not be repeated here. Attention is called to that part of the discussion for such details.

Morgan County, as has been brought out in the part dealing with levees and embankments, was a heavy loser on account of the flood. The public road and grade and the approaches to the bridge at Waverly were rebuilt at a cost of $1,200. (See Figure 21, for the condition immediately after the flood.) At Henderson bridge, where great damage was done to the high public road embankment across the valley, the cost went far into the thousands. It was found necessary to build another span to the bridge one hundred seventy-five feet in length, where the current had widened the channel on the south side. This span of bridge cost $9,000. The high grade was replaced as it was before, at a cost of $3,800. As has been said on a preceding page, the damage here was almost entirely due to the insufficiency of the opening under the bridge.

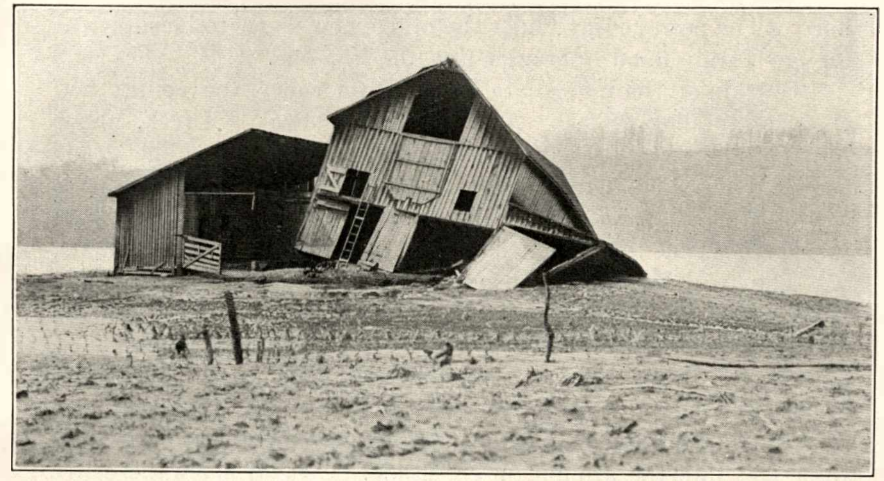

Fig. 46. Montgomery barn after the water had withdrawn. The water washed a hole under the corner sufficient to wreck the barn.

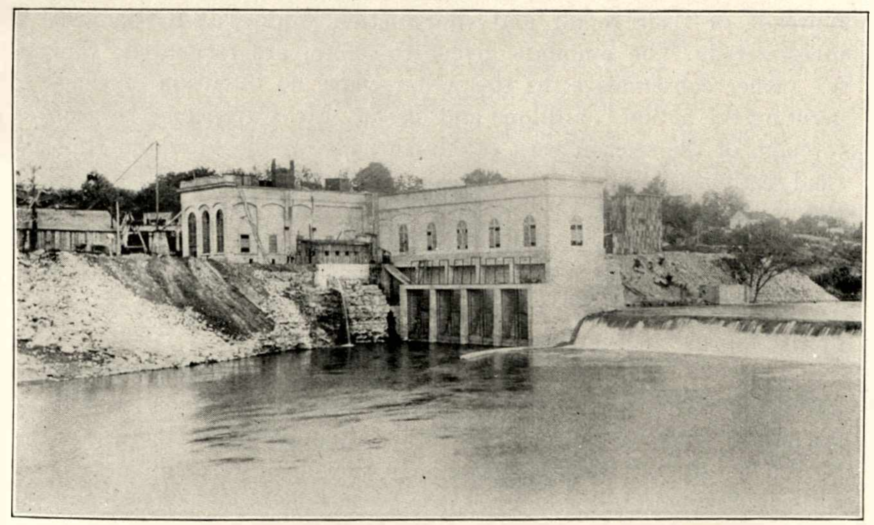

Fig. 47. Power plant at Williams, Ind.

This condition has been remedied by the new span of bridge, making the opening at least one hundred feet wider than it was before the flood. The passage way under the bridge now seems to be sufficient for any future flood approximating the last one.

Outside of the immediate White River valley, the county had expenses totaling $8,000. A bridge across Scott's Creek, above Martinsville, four miles from the river, cost $3,500. The grade across White Lick Creek, west of Mooresville was repaired at a cost of $700. Elsewhere over the county the repair work amounted to $3,800. Thus the total expense to the county itself was $20,000.

The road leading northwest from Martinsville across White River valley was washed out. The part between the river and the city of Martinsville, a stretch of 3,900 feet, has been replaced by pavement. This structure is undoubtedly flood proof. Pavement brick slushed with cement has been laid upon an eight-inch concrete bed. Curbing on a level with the pavement has been sunk three feet into the ground on each side. Cement sidewalks three feet wide have been placed on each side of the curbing. The entire structure is more than thirty-three feet wide. It was built by Washington Township and the city of Martinsville at a cost of $20,000. (See figure 47.)

It was found almost impossible to get the exact cost to the railroads of their repair and construction work within the area investigated. The amounts given, therefore, are estimated; they are rather conservative, as the writers have no intention of exaggerating the actual conditions and losses. Mr. Carmichael, section foreman of the section west of Martinsville on the Vandalia Railroad, estimated that the cost to put back the grade and track of the one and one-half miles washed out, was $10,000, and that the one and one-half miles north of Martinsville cost an equal amount. The Interurban Line was injured as much, if not more, than the Vandalia Railroad north of Martinsville; therefore, a safe estimate of the expense to the Interurban Company would be $10,000.

The city of Martinsville itself suffered considerably during the flood, since the water ran swiftly through the main streets. No houses were actually carried away, although the water was in several hundred of them. Damage to the furniture could not be estimated unless a house to house canvass was made, and even then it could only be approximate. Mr. J. W. Anderson, the present mayor, estimated that the expense of the city in taking care of the people, in feeding them during the flood, in cleaning up the streets after the flood had subsided, and in paving a small stretch of one street that was torn up, was not less than $10,000.

This completes the items of cost coming within the scope of Morgan County. The total estimated expenditure of all the corporations which were injured by the flood was $80,000. This is perhaps as accurate as it is possible to get at present.

Owen County was exceedingly fortunate in the matter of damage to county structures. No county bridges or road-grades were washed out in the White River region. The grade and approach to the river bridge at Spencer was repaired at a cost of $300, and the approach to the bridge at Freedom was repaired at a cost of $100. This total of $400 is rather small in comparison to the cost in several other counties.

The railroads in the county, however, were not so fortunate as the county. The estimated cost to the Monon at Gosport was not less than $8,000 in rebuilding the half-mile of grade and track and in repairing the injured pier at the bridge. The Vandalia in Owen County was not injured very much in any one place. In the 'Narrows' above Spencer, some of the track was turned over and the grade slightly washed. A small portion of the grade and track was washed at Freedom. The estimated cost to the company to repair the above damage is $5,000.

The town of Spencer was flooded in the part next to the river. Little damage was done outside of wetting furniture. Altogether, four houses were moved from their foundations; one house across the river was carried entirely away. This private loss was in the neighborhood of $2,000. The cost to the town of cleaning up the streets after the flood, in repairing sidewalks, and other incidentals was about $1,000. These estimates were given by Mr. Steven Summers, a member of the town board. The total estimated loss in the entire county was, therefore, $16,000, a small amount as compared with the preceding county.

Mr. C. H. Jennings, Auditor of Greene County, gave the total cost to the county in repair of roads, rebuilding of bridges and grades, etc., as $40,000. Of this amount, $10,000 was spent for bridges. The county bridge west of Bloomfield was being repaired at the time of the flood, and several hundred dollars damage was done which had to be made good by the contractor. Special attention was given to the county road-grade west of Bloomfield. This grade was repaired at a cost of $2,300, but it was graded down two feet lower that it was before the flood. On top of this grade has

been placed a concrete pavement eleven inches thick, twenty feet wide, and four thousand four hundred feet long. This pavement cost the county $3,300. This embankment across the valley is built on a water level line, about seven feet above the valley land at the bluff and twenty-five feet above it near the river. It will average perhaps twelve feet above the valley land. There is nothing to protect the embankment but the pavement on top. Should the water rise approximately as high as it did in 1913, the water would pour over the embankment its entire length and undermine the concrete on the lower side. In order to make this embankment flood proof, some sort of an apron must be made on the lower side to prevent the water from cutting under the pavement. This undoubtedly should be done or the present structure is in serious danger. The cost of building a cement apron on the lower side of the embankment would be probably as much as has already been expended upon it, but it certainly seems necessary. Such a structure is far more in danger of destruction than one built on a level with the valley as is the case at Martinsville.

The grade at Newberry has been rebuilt and the abutments of the small bridges replaced.

The town of Worthington was inundated on its western side by the overflow from Eel River. No houses were washed away, but a great many were badly flooded, ruining much furniture and household goods, thus causing considerable personal loss. The loss of the C. & E. I. R. R. was about $1,200, where the flood waters broke over the embankment allowing the western part of Worthington to be flooded. The C. & E. I. R. R. was injured at two other places in Greene County. About one-half mile of track and grade was taken out near where it crosses Lattas Creek, northwest of Bloomfield, and below the river bridge north of Newberry over a mile of track and trestle was taken out. The estimated cost of repairing these two places is $7,000.

The I. C. R. R. with its long stretch of high trestle work across the valley west of Bloomfield received but little damage. (See Figures 26 and 27.) An estimate of $2,000 would be rather high. But the Monon Branch received severe damage. The estimated cost of repairing it is $7,000, and it is yet in a very bad condition.

The total estimated expenditure for all the structures in Greene County and the repair work is $57,200.

Daviess County itself sustained but little loss in the White River region. A bridge in Washington Township which had not been completed was injured some, and the loss fell on the Vincennes

Bridge Company. The great loss in Daviess County was received by the B. & O. R. R. Co. It is impossible to get more than an approximate estimate of what it cost to replace the bridge across the river, four and one-half miles west of Washington. Nearly a hundred men were employed for over eight months. It took nearly all summer to build the pier in the middle of the river. This pier is built on bed rock sixty-five feet below the surface of the water; at its base it is forty-five feet wide, and is long enough on top for a double track. The butments of the new bridge were set back some twenty feet, making the opening under it some forty feet wider than formerly. The new bridge is approximately six hundred feet in length. This bridge could not have cost the B. & O. R. R. Co. any less than $100,000, and may have cost much more. A mile and a quarter east of the river bridge is 'Blue Hole,' where about four hundred feet of track and trestle went out, and with it a train which was being used in placing sand bags on the grade between there and the river. The waters must have rushed through this opening with tremendous speed and force. The hole, for it is a hole, is 350 feet wide, 700 feet long, and 40 feet deep. In the rebuilding of the trestle, carload after carload of rock ballast was dumped into the place, so that now it shows above the water under the trestle. The engine that went down in the hole was afterwards raised and now is in service in the yards at Washington. 'Blue Hole' was started in the flood of 1875, and has given more or less trouble ever since. It was made about twice as large during the last flood as it was before. Evidently, it cost the B. & O. R. R. Co., several thousand dollars this last year, no less than $6,000, considering the large squad of men they had hunting for two weeks for the bodies of the men drowned in the flood.

The total estimated expenditure, then, by the B. & O. R. R. Co. in Daviess County is $106,000, and it was probably much more. The bridge replaced, however, is much better than the old one. The extra forty feet opening will be a great help, but it would undoubtedly have been much better and safer to have had the opening made much wider through the use of trestle work. The grade through the valley was so high that the water never got above it at any place, but was forced to go through the few narrow openings. The concentrated force of the waters is what caused the damage at the river bridge and at 'Blue Hole.'

The C. & E. I. R. R. Co. lost about one-half of the bridge on the East Fork, between Washington and Petersburg. As yet they have not replaced it, but are carrying on traffic over a tem-

porary trestle-work. The cost of building a bridge here would be much less than the one west of Washington. The river flows over bed-rock at this place; it is near the bluff line. A bridge could be built easily for $50,000.

Martin County will be considered next. The repair of county structures was limited to the grade and sidewalks in West Shoals in the White River region. The expenditure here was $300. The town of Shoals itself suffered more than any other town in the area investigated. Forty-four houses were moved from their foundations, eleven of which were carried down the river. Nearly all of these houses were situated in the old valley (see special plate), east of Shoals, where the water swept around the town, washing out the B. & O. R. R. grade. None of these houses were fine residences. Hon. H. Q. Houghton, who was chairman of the Relief Committee, estimated that the entire personal loss was $30,000. The Relief Committee used $4,500 in replacing, remodeling, and refurnishing the houses. Some kind of a house was replaced in the place of each one that had been moved by the flood waters, with four exceptions. The families of these four showed no interest or disposition to help, and were passed by.

The B. & O. R. R. Co. lost about one and one-half miles of grade and track at Shoals and some two miles below. The replacing of this grade and track cost not less than $10,000. The grade was rebuilt in a veritable levee across the old valley in the eastern part of Shoals, ready to be washed out again by the next flood approximating the recent one.

The entire value of all that was lost within the White River region of Martin County is estimated at $40,300. This includes the estimated $30,000 loss to the inhabitants for whom $4,500 was spent in replacing their structures. But since the $30,000 loss is the ultimate loss, these figures are counted.

Lawrence county was far from being fortunate in the way of losses to county and railroad structures. The county bridge at Rivervale was replaced at a cost of $16,484. The span added to the south side of the bridge below Bedford on the Bedford and Mitchell pike cost $4,250. The bridge, which was carried fifty feet up stream by the rapid rising back waters, about one-half mile from the river up Guthrie Creek, cost $3,305. The Salt Creek bridge cost $5,150. The cost to the county in the way of road repair on account of loss due to the flood was about $3,000. The total expenditure of the county itself, therefore, was $32,190. There

Fig. 48. Power plant at Williams when the flood was highest, 31.12 feet above the crest of the dam March 29.

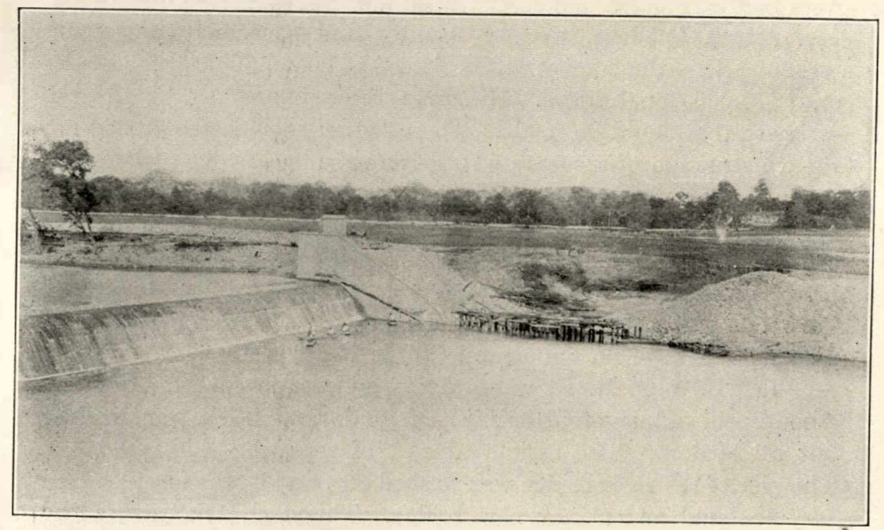

Fig. 49. East end of the dam at Williams. The hole was cut by the flood in January and was made very little larger by the March flood.

were other expenses, however, incidental to the reconstruction work. These figures are merely contract prices.

The B. & O. R. R. Co. had one-half mile of track and grade washed out at Rivervale. The bridge remained intact. The estimated cost of reconstruction here is $4,000. The branch line of the B. & O. from Rivervale to Bedford also met with considerable damage where it crosses the river below Bedford. Over one-half mile of track was removed and about two hundred feet of grade. The total expenditure on the entire branch was perhaps $4,000.

The Monon was a heavy loser, both in the White River stretch and in the Salt Creek region. At White River below Bedford, about one-half mile of track was taken away, a small part of the grade was washed out, and the bridge was slightly injured. The cost here was probably $3,000. In the Salt Creek region north of Bedford about a mile of track was taken out and the grade was badly injured. The cost in this region was not less than $4,000.

Thus, the entire estimated amount spent in the confines of Lawrence County for reconstructional purposes was $47,190.

Jackson County, with its wide valley expanse in the region above Brownstown and Seymour, and the valley of Muscatatuck River, was the heaviest sufferer in the way of expenditure for reconstructional measures. Practically two hundred miles of pike roads were badly damaged and some fifteen miles were entirely destroyed. Mr. Albert Luedtke, County Auditor and a former contractor, estimates that the county will be forced to spend $50,000 for roads, and $25,000 for bridges. He gives these figures as the lowest estimate that could be made. These figures include the $6,000 for the construction of a concrete road from the lower edge of Brownstown to the river, a stretch of a little over a half mile. This road will be similar to the concrete road at Bloomfield with the exception that it will be built on a level with the valley and instead of being built on an embankment or levee. This will undoubtedly be much better, as it will be flood proof. The waters can pass over it, and have no opportunity to do it any damage.

The B. & O. R. R. was a heavy sufferer in Jackson County. About one and one-fourth miles of grade and track was washed out at Medora. The estimated cost of replacing this is $8,000. The pier of the river bridge was washed out, and it was found necessary to build an entirely new bridge. The steel structure of the old bridge is still lying in the river. The estimated cost of this bridge is not less than $50,000. Much trouble was experienced in putting in the pier and the cost may have been much more.

The Southeastern Indiana Railroad suffered considerably in the stretch across the wide valley west of Seymour. Not less than three miles of track was washed out, several short stretches of trestle taken away, and the grade badly washed. The damage approximated $20,000.

The town of Medora suffered considerably on account of the water getting into the houses and damaging household property. No houses were moved or injured otherwise. The personal damage to the town does not come within the scope of this part of the report, since it treats of the reconstruction work mainly. Furthermore, the personal damage is very difficult to estimate in dollars and cents.

The total estimated expenditures in Jackson County reached higher than in any other county coming within the area of investigation. They amount to a total of $152,000.

The expenditures for reconstructional work in the various counties investigated in brief are as follows.

Morgan	$80,000
Owen	16,300
Greene	57,200
Daviess	106,000
Martin	40,300
Lawrence	47,190
Jackson	152,000
Total	$498,990

Practically ninety-five per cent of the above half-million dollars was spent by corporations. While this money was a direct loss to the corporations and the people as a whole, such a loss is not at all to be compared to the personal losses that were suffered along the river by the private individuals. The losses to the individual land owners, as has been partially brought out elsewhere in this report, mean far more, so far as actual suffering is concerned. Loss of crops, live stock, household goods, and buildings gave individual injuries that in some cases will never be recovered from. It is to be lamented that such losses cannot be much more than guessed at; and again should they be approximated, they would seem small in dollars and cents as compared to the losses that have been given. They were individual, and generally to individuals who could ill afford any loss at all. Renters in some parts of the valley lost practically all that they had. Everyday laborers in the towns, such as Shoals, lost practically all that they possessed. The things in themselves may seem very little, but to the individuals, their loss left the future very dark and gloomy indeed.

Relation Between the Flood and Sickness

The advent of any considerable flood upon a town or city is sure to cause a great amount of anxiety, for in the past it has always brought with it an increase of disease and sickness. This statement is borne out in the newspaper clippings of the preceding pages which were written after the flood of August, 1875. It has been impossible to find out whether or not there was an increase in disease after that flood, but such must have been the ordinary consequence of a flood, or the suggestions referred to would not have been made at that time.

Several letters were sent out to the health officers of the various cities that were partly inundated, asking about the sickness that occurred as a result of the recent flood. Some of the representative letters received in reply are herein duplicated. It was with considerable surprise that the tenor of these letters was noted. It was fully expected that there would be a notable increase in disease in the parts of these cities and towns that were inundated. The results were just the opposite. The possibilities were there, but the health officers arose to the occasion and clearly demonstrated that disease of a contagious nature can be wiped out of existence even under the most adverse conditions due to a flood. Would it not be a good investment for such action to be taken even when there are no floods? Human life is as dear at one time as another. It is shown that it can be conserved, hence it is our duty to take measures along that line, and make even more progress than we have made in the past. If a man is imprisoned in a mine, there is no limit to the amount of money that will be spent to rescue him. The last flood showed that there are many lives lost each year by disease that could be saved, if such energy as was exerted after the flood were to be continued for the same length of time each spring. It appears that this is one of the most important facts that has been brought to light by the investigation of the flood conditions of White River, and it is hoped that a little of this sort of energy will be spent each spring in cleaning up the poorer districts of our towns and cities. As a rule, the flooded districts are inhabited by the poorer class of people, living under improper hygienic conditions. If these conditions could be righted each spring, much less disease would prevail, and loss of life would be considerably curtailed.

Noblesville, Ind., December 5, 1913.

Dear Sir:

Your favor of 4th inst. at hand. Immediately following the flood and for some time after, we had a force of men working to clean the district over which the water had ranged. Free disinfection was given in all parts of the city and everyone was compelled to clean cellars subject to the approval of the Health Department before they might return to their homes. In addition, free typhoid immunization was offered and taken advantage of. Consequently there was reported during the month of April, only one contagious disease, namely scarlatina, and that could in no way be attributed to the flood. As to the general state of health following the flood, my inquiries among the physicians lead me to believe that in the city there was little or no effect. Typhoid has been a minus quantity with us this year and the consensus of of opinion among all is that the most that could possibly be attributed to the flood in this vicinity only includes a few attacks of tonsilitis with the consequent rheumatism. Across the river from the city have occurred two cases of diphtheria that might possibly be connected with it.

Any further information that I may be able to give will be tendered very willingly if you will only let me know.

Yours most sincerely,

H. H. Thompson, M.D.

Shoals, Indiana, Nov. 29, 1913.

Dear Sir:

In reply to your inquiry I beg to say that there was not as much sickness following the last spring flood as was usual in this community in previous years. I am unable to account for the unusual healthful condition that prevailed here all summer in comparision to other years.

Respectfully yours,

Chas. E. Stone,
County Health Commissioner.

Indianapolis, Indiana, Dec. 5, 1913.

Dear Sir:

There has been less sickness in the flood district during the last year than at any time for several years.

Diphtheria, scarlet fever and other infectious diseases have been fewer this year than for the past two years. During the fall months, typhoid fever, the disease which you would naturally expect to make its appearance as a result of the unsanitary conditions left by the flood, is not as prevalent in that district as in other parts of the city. If fact, all sickness shows a lower rate in that part of the city than during the previous two years. This may be attributed to the fact that a concentrated effort was made to clean thoroughly the flooded district and leave it in as perfect sanitary condition as possible.

When we finished the work, I made the remark that West Indianapolis was in a better condition than it was before the flood. I believe that the statistics on disease in that district would bear this out.

Yours very truly,

H. G. Morgan,
(Health Officer.)

SPENCER, INDIANA, December 4, 1913.

Dear Sir:

Replying to your inquiry of this date, I will say that there was very little sickness occurring in this community that could be attributed to the flood. In the four months immediately following the flood there was less sickness in Spencer, than for the corresponding time in any year for the last twenty years.

Very respectfully,

ALLEN PIERSON, M. D.,
(County Health Officer.)

FLOOD OF 1875 COMPARED WITH THE RECENT MARCH FLOOD

The flood of 1875 came in the last days of July and the first days of August. It was of about the same height as the recent flood. Coming in August, it caught the crops, corn, wheat and oats, and caused much more damage than the March freshet. There are many conflicting reports of the relative stages of the two floods. A number of reports showed that the August flood of 1875, was twelve or eighteen inches higher than the March freshet. About the same number showed that the last flood was as high, or higher. These conflicting reports may be explained as follows: During the last thirty-eight years there have been many obstructions, such as public roads being graded up, interurban grades, and steam railway grades. In each case the man above the obstruction declared that the March flood was the higher while the man below the obstruction was very sure that the flood of August, 1875, was the higher.

The reports between the obstructions showed that the two floods were about the same height. By the occurrence of the recent flood in March, there was no space taken up with green vegetation and growing crops. There is much less timber in the White River bottom now than thirty-eight years ago. So, on the whole, there seems to have been considerable more water passing down the West Fork last spring than in August, 1875. The flood of 1875, on the East Fork was not in any way to be compared with the recent freshet, which was from seven to ten feet higher than any previous high waters.

The following newspaper reports will give some idea as to the conditions of the floods:

(Special to the Indianapolis Journal.)

MARTINSVILLE, IND., August 6, 1875.—The waters here are subsiding. White River is slowly falling, but it will be several days yet before it is within its banks. Running as it does through the best portion of the country—through the great corn and hog section—its damage to our farmers and people is immense. Acres of fine growing corn and wheat in the shock that a few days ago gladdened the hearts of the grangers who possessed it, are ruined and wholly lost. All the creeks and other small streams have been flood high, inundating whole farms, thereby destroying crops, carrying away fences, and doing other damage. Many of our roads have been rendered impassable and the bottom land stripped of the fences. The loss of Morgan County by rain and flood will not fall below a million dollars, and all kinds of trade and business will be stagnated for the next twelve months. The Vincennes Railway here and for several miles above and below, is badly damaged and it will be several days before it will be in condition for the regular running of the trains. Large quantities of old corn stored near the river have been washed away and otherwise damaged by the raging waters. The wheat, oats and hay in the highland have been badly damaged by the late rains.

(Special to the Indianapolis Journal.)

SHOALS, IND., August 3, 1875.—The rains in Randolph County, which from the head waters of the East Fork, raised the river from ten to twelve feet, in many places filling the banks to their utmost capacity. The storms Saturday night and Sunday, in which water fell in Martin County to the depth of four inches, have completed the disaster. It is useless to speak of the crops: they were unusually promising, and now they are destroyed. As a result of the inundation the sandstone bluff on which Shoals is built, is an island.

Indications are that the river once ran east of the town, along the level bottom lands. It is supposed that some convulsion of nature changed it to the west side. The water is over the site of the old channel. To make this more complete, an ambitious creek joins with its waters. Fields of corn and wheat are covered, fences are washed away, and the lives of the residents are endangered. Ingress and egress are to be obtained only in canoes or on the railroad.

It is feared that the back waters in time will be productive of much sickness. Thousands of acres of land are covered with water in this portion of the county, the water reaching to the branches of the trees in the forests, in the bottom land. The water is still rising at the rate of an inch per hour.

In January, 1847, in June, 1856, and in September, 1866, the East Fork was exceedingly high, but the greatest damage attends the present overflow on account of the crops.

(Indianapolis Journal, August 7, 1875.)

No one who has not passed over the track of the late flood can form an adequate idea of the vegetable decay that it must produce. All along the river and its tributaries the weeds, as well as the good part of the crops are 'cooked black,' wilted, and sure to rot in the hot sun and remaining moisture so fast as to create a general miasm. Already the black water of the 'Old Bayou,' next to the Vandalia Railroad is covered with that thick green scum that says, malaria, chills and fever, as plain as if every shoot of fungus were a tongue. This is but one of a myriad ponds left by the retreating waters. A great deal of corn is washed or broken down, and its decomposition, as well as that of the overturned oats and grass, and the soaked logs, and refilled swamps, will swell the dangers of infection.

(Special to the Indianapolis Journal.)

Shoals, Ind., August 9, 1875.—White River at this place has been higher at this time than at any other rise. The back water has entirely surrounded Shoals, as previously reported, attaining a depth of seven to thirty feet. Yesterday the river began falling. The prospect is not very cheerful, as the smell of rank vegetation is very perceptible. It is feared that sickness to an unusual extent will prevail. Two hundred families were compelled to move from their homes, situated for the most part in the valley east of town, and partly in the furnace village of Irontown, a mile up the railroad.

(Indianapolis Journal, Saturday, July 31, 1875.)

The Floods of 1828 and 1847.—The flood of 1828, which old settlers considered the highest ever known, washed a region wholly destitute of population and production, and the injury was comparatively light, although serious enough, we believe, to induce the legislature to remit the taxes or to extend payment on the inundated lands. The flood of 1847, it will be remembered by the older class of citizens, came nearly up to the flood of 1828, but not quite. But even at the later period, White River Valley did not contain more than one-fifth of the population that it does now, and only a little more than one-fifth of the wealth, as is shown in the comparative tables of the census, and the recent estimates of the Board of Equalization. The inundation, therefore, though larger than the present one by two or three feet, could not have done more than a small proportion of the harm done by the recent flood.

(Special to the Indianapolis Journal.)

Worthington, Ind., August 5, 1875.—As the flood is the only thing talked about in this locality, I have concluded to furnish you a few items in regard to it. It was the highest and the most disastrous freshet ever witnessed by the oldest inhabitants. It was twelve inches higher than it was during the memorable flood of January, 1847, on White River and Eel River. Our town has been situated on an island for four days, the water being from six to sixty feet in depth in all directions. Work is suspended. All corn and wheat on White River bottom, in Greene County, for a distance of twenty-five miles have been swept away and nothing has been saved. In addition to all of this, all of the fencing has gone down the river with the products of the soil. The crop on the prairies is a total failure, due to the wet weather. It has been estimated that the damage in this county alone to the crops, and by the loss of fencing, lumber, etc., will amount to $300,000.

PART III.—FLOOD QUESTIONS

Increase of Floods

Are floods increasing, and if so, why? Leighton, in 'Water Supply Papers No. 234,' answers the question with a very emphatic affirmative. He bases his statements on the results of observations extended from 1875 to 1907, upon the Ohio River, the Allegheny River, the Monongahela River, the Youghiogheny River, the Wateree River, the Savannah River, the Alabama River, and the Connecticut River.

In the region studied, he gave the cause of floods and the cause of the increase of floods as follows:

1. Climate (including rainfall, evaporation, temperature, wind and humidity.)
2. Topography.
3. Geology.
4. Vegetation. (Deforestation, growing crops, etc.)
5. Artificial agencies (including breaking of dams, drainage, etc.).

He says, 'Summarily, therefore, it may be stated with confidence that the increase of flood tendency is due by far the largest measure to the denudation of the forest areas.'

It seems that, in Indiana, the deforestation of between 80 and 85 per cent of the total area of the State has had something to do with the increase of flood frequency and flood height. This is especially true of the southern part of the State, where the slopes are more steep and the country more broken. According to F. A. Miller and E. E. Davis ('Eighth Annual Report of the Indiana State Board of Forestry,' 1908), the most noticeable change in the activities of the Wabash River due to deforestation is the fact that it rises and falls more rapidly now than formerly. In three or four days it reaches a height that formerly took two or three weeks; however, the fall of the flood crest is now sudden, as the rise. Some seem to think that deforestation will cause the rainfall to decrease, or, if not decrease, to be distributed more unevenly through the year. This has not been satisfactorily proved. However, the following discussion will give the reader some idea as to the nature of the work that is being done in trying to arrive at some definite conclusion. Dr. Raphael Zon in *Science* (N. S. Vol. XXXVIII. No. 968), shows that there is a close relationship

between forests and precipitation. He uses the forests and precipitation of the eastern half of the United States to illustrate his point.

Dr. Zon starts his discussion by bringing up the fact that the eastern half of the United States receives its rainfall from the air currents that come from the Gulf of Mexico and the adjoining ocean. He then cites the work of the noted European meteorologist, Professor Bruckner, who has computed the amount of water evaporated from the land surface and the ocean surface, and the amount of water that is returned to the land and the ocean in the form of precipitation, and who has shown that the regions at the periphery of the continents are able to supply seven-ninths of their precipitation by evaporation from their own areas. In other words, the humidity derived from the ocean is precipitated in a narrow strip along the coast and even there consists of only about two-ninths of the precipitation falling in those regions. This being the case, Dr. Zon suggests that the air currents from the gulf region, upon leaving the coast, drop the humidity acquired over the Gulf, and, as they pass farther north gather up a new supply of moisture which will be precipitated farther on. If it were not for the evaporation taking place on the land, all of the larger continents would have large desert regions at their interior.

Then Dr. Zon cites the results of the researches of Professor Henry, in his recent investigations on the effect of forests upon ground waters in level country and the work of Dr. Franz R. von Höhnel, of the Austrian forest experiment station at Mariabrunn, who have shown that a forest area returns a large amount of water to the atmosphere. Then Dr. Zon says: 'The most valuable and complete work on the subject is by Otozky, a Russian geologist and soil physicist, which appeared as a publication of the forest experiment stations. Otozky worked up an enormous amount of observations, both his personal and those furnished him by other people, and did not find a single contradictory fact. His conclusion is that the forest, on account of its excessive transpiration, consumes more moisture, all other conditions being equal, than a similar area bare of vegetation or covered with some herbaceous vegetation.'

He continues the discussion as follows: 'If the present area occupied by forests in the Atlantic plain and the Appalachian region were instead occupied by a large body of water, no meteorologist would hesitate for a moment to admit that the water surface has a perceptible influence upon the humidity of the central states and the prairie region. Should not, therefore, forests which give off into the atmosphere much larger quantities of moisture than a free water surface, have at least a similar influence upon the region into which the prevailing air currents flow.'

Then follows the interesting studies made by Professors Francis E. Nipher and George A. Lindsay on the rainfall of the State of Missouri, and the discharge of the Mississippi River at St. Louis, and at Carrollton, Louisiana. To quote from his article: 'Nipher found that the average discharge of the Mississippi River at St. Louis during the ten years ending December 31, 1887, was 190,800 cubic feet per second. The amount of water falling upon the whole state during the same interval was 195,800 cubic feet per second, or within two per cent of the discharge of the Mississippi River at St. Louis. If, however, a comparision is made between the total rainfall on the basin draining past St. Louis, and the river discharge at that point, it appears that the drainage area of the Mississippi and the Missouri Rivers above St. Louis, is 733,120 square miles, or over ten times the area of Missouri. These figures show that a small portion of the total rainfall over the drainage basin of the Mississippi River is led into the rivers and conducted back to the sea. It is evident that by far the larger portion of the precipitation that falls over the drainage basin is evaporated back from the land into the atmosphere, and is not returned to the sea through the medium of drainage. These figures show further that the source of precipitation of the Mississippi drainage area is from evaporation over the land and not derived from evaporation over the sea. Mr. Lindsay computed the discharge of the Mississippi River at Carrollton, Louisiana, and found that the average for fourteen years was 117 cubic miles per year, or 545,800 cubic feet per second, which is less than three times the precipitation over the state of Missouri.'

It seems to the writers that forests have something to do with the amount and distribution of the rainfall of the Ohio Valley. It is impossible to say, how much, until a long series of experiments over the entire drainage basin of the Ohio Valley are perfected. Owing to the rapid decrease in our forest areas these experiments should be carried out as soon as possible, for it takes many years to replace a forest once it is entirely removed.

Deforestation in the northern part of this State has had less to do with the increase of flood frequency and height than the great amount of ditching that has been done in the last forty years. The ditching has been of two kinds; first, large open ditches known as

dredges, and second, the tile drains that feed the former. The following is the amount of tile drains and dredge in three of the northern counties:

Fulton County. In Fulton County there are 75 miles of open dredge ditch and an equal number of miles of tile drains, twelve inches in diameter or larger. Feeding these dredge ditches and larger tile drains there are hundreds of miles of smaller tile drains. In fact, this county is underlain with a net-work of small tile drains that tend to hurry the rainfall to the larger streams. The immediate run-off is greatly increased thereby, the flood height is increased, and the duration of high water lessened.

Starke County. A letter from the surveyor of Starke County written to the writers will be given, as it explains the situation very well.

Sir: We have about 190 miles of dredge ditch in this county, of which 135 miles have been completed within the last ten years. We have about 20 miles under construction and petitions are on file for 50 miles more and the Commissioners are acting on 5 miles more.

There are between 45 and 50 miles of tile drains 10 inches or larger in the county. My opinion about the high water is as follows: the trouble lays in the poor outlet that we have for our lowland ditches. We have opened out marshes and lakes into the streams and never once give it another thought. When our marshes receive a heavy rain fall the good ditches rush the water to the rivers and cause floods, and will do so until we get a final outlet or close our ditches to hold the water.

Yours respectfully,

CHAS. A. GOOD.

St. Joseph County. In this county there are 110 miles of dredge ditch and more than 30 miles of tile drains, that are twelve inches in diameter or larger.

These three counties are a fair average of the northern part of the State. North of the Wabash River it is possible to control the floods in a large measure, if not altogether. It might be possible to put dams across the outlets of the numerous lakes. These dams should be equipped with flood gates that could be lowered in times of excessive rainfall, thus ponding the water until the crest of the flood has passed. Later the flood gates could be opened and the lakes lowered to their normal condition. Also a small amount of power could be made in this manner. Silt may be collected that otherwise would be carried to the Gulf. Better still, instead of letting the water out of the lakes after the streams have carried away the flood waters that could not be controlled, the excess water might be kept stored or ponded and in times of drouth, which occur so often in Indiana, it might be applied to the fields, insuring a yield where applied.

It might be possible to close the tile drains and some of the smaller open ditches while there is an excess of rainfall, and, after the immediate run-off has escaped, these tile drains could be opened again. This would not hinder farming to a great extent and would give the water time to soak into the ground instead of being rushed off to the rivers. Some sediment might also be kept from being carried away. The amount of water that will soak into the soil or ground depends on the nature of the soil, the length of time that the water is exposed to the soil, and the temperature. That is, a light sandy loam or a muck soil will absorb surface water much faster than a fine impervious clayey soil. King, of Wisconsin, has shown that a clay soil will hold water much longer than the sandy soil.

The great number of various kinds of ditches in Northern Indiana carry the water away so rapidly that it does not have time to soak into the ground. This also tends to lower the water table, thereby making the distance that the water must travel by capillary attraction greater as it comes to the surface to feed the growing plants. Also the greatly reduced forest area permits the water to escape more rapidly, less water is absorbed into the ground, the immediate run-off is increased, and the flood stages are correspondingly heightened, while the low water stages are much lower. When the ground is frozen it is impossible to control the immediate run-off.

The imperfect records of the Kankakee River show that the flood stages are getting higher and that the low water stages are getting lower and of longer duration. Thirty years ago the ordinary low water discharge at the mouth of the Kankakee River was something near 1,300 cubic feet per second. As near as the writers are able to find out, the low water discharge at the present time is less than two-thirds what it was thirty years earlier.

The rainfall during the last thirty years has not perceptibly fallen off nor does it seem to be greater during the winter months now than formerly or less during the summer months than thirty years earlier. Thus it seems that deforestation, and increase in the number of dredge and tile ditches have caused the flood heights to be increased and the low water stages to become lower and of longer duration.

The writers are not so sure that there has been a *decided in-*

crease in flood frequency in the Ohio Valley during the last forty years. For instance, Professor Alfred J. Henry (Bulletin 'Z' of the United States Department of Agriculture Weather Bureau) has shown that by taking the severe floods of the last forty years, on the Ohio River, there were 19 severe floods during the first 20 years, and 32 during the last 20 years, ending 1910. Now if the last 30 years are divided into two equal periods and the first 15 years compared with the last 15 years the order of frequency is reversed. The following table taken from 'Bulletin Z' of the Weather Bureau Publications shows the above in tabular form:

TABLE No. 6.

STATIONS.	First period of 20 years, 1870–1890.	Second period of 20 years, 1891–1910.	First period of 15 years, 1881–1895.	Second period 1896–1910.
Pittsburg	2	9	3	8
Cinccinnati	6	7	8	5
Louisville	5	5	7	3
Evansville	6	11	8	9
Totals	19	32	26	25

It is a fact that great floods are dependent upon excessive rainfall; also it is a fact that deforestation and the increase of artificial drainage have a tendency to rush these excessive waters to the main streams, causing the height of the flood to become greater in a shorter length of time. Just how much that this will increase the height cannot be determined until more data are accumulated, showing the discharge of the streams and the amount of precipitation over large and various areas. Mr. Henry suggests that it will take at least 50 years to get together sufficient data to determine the effect.

The Lowering of the Water Table

It is beginning to be a well known fact that the water table over the entire State is being lowered. This is the case in several states scattered over the United States, as in Michigan, Alabama, Florida, California, Colorado, Nebraska, South Dakota and Washington. In these states laws have been enacted so as to prevent the unnecessary waste of the underground water. The following table will show to some extent the amount that the water table is being lowered in Indiana. This data was published in the Proceedings of the Indiana Academy of Science, for 1910, by Mr Charles Brossman.

TABLE No. 5.

CITY.	Total drop.	Years.	Feet per year.
Kentland	48	5	9 4-5
Elwood	40	12	3 1-3
Greensburg	40	10	4
Muncie	28	....	....
Remington	8	10	4-5
Marion	6	20	3-10
Butler	4	10	2-5
Linton	30	6	5
Kokomo	15	15	1

These towns are pretty well distributed over the State and are a fair representation of the State at large. The last column shows the average fall in feet per year. If this is a fair test, it will not be very long, possibly it may occur even in this generation, until the water table will be so lowered as to become a very serious matter.

Mr. F. G. Clapp, of the United States Geological Survey, believes that the decline of the water table is due to the following causes, named in the order of their importance:

1. Waste of Water.
2. Surface drainage by ditching for cultivation.
3. Over-development of the underground water.
4. Deforestation.

The people of the United States do not seem to realize that the natural resources of this new country are limited. Resources such as coal, oil, gas, timber and water,—especially the first four, are the result of many years labor on the part of Nature, and cannot be replaced when once exhausted.

Water, the most abundant of all our natural resources, is becoming a luxury, and it behooves the present generation to consider and start a movement for the conservation of it. In Madison

County there are at least 100 flowing wells which average twenty gallons per minute. This would make a total of about 1,700,000 gallons per day, or more than enough water for a city of 30,000 inhabitants without extensive manufacturing plants. These wells could be closed up when not in use. If this water was being used it would be permissible, but to let it be wasted is resulting in materially lowering the water table each year.

The loss of water is not the only offensive thing to be considered. Dr. J. W. Beede, of Indiana University, in a paper before the Indiana State Board of Health, has shown that old adjustments are broken as the water table is lowered, thus causing what once was good water to become unfit for use. The water that makes up the water table is not derived from an inexhaustible source, but in a large measure depends upon the immediate rainfall, and if this is carried away by an elaborate system of ditches, but little water will have a chance to soak into the ground to replenish the lowering water table. On the other hand the water is carried away at once and helps to increase the height of the flood stage. It seems that it is absolutely necessary to drain our cultivated fields, but in doing so there should be some way by which we could retain the surplus waters and thus permit some of them to return to the ground, raising the lowering water table, and, by decreasing the immediate run-off, lessen the flood height and intensity.

Another source of waste of water is the great amount of water that is so recklessly used in cities. Ordinarily in a city where there is not much manufacturing, 40 gallons per capita per day is sufficient for all ordinary needs. As a rule there are many times that amount pumped. The following cities all use more than is necessary:

Rochester	125 gallons per day per capita.
Goshen	150 gallons per day per capita.
Peru	100 gallons per day per capita.
Danville	150 gallons per day per capita.
Lebanon	100 gallons per day per capita.
Washington	125 gallons per day per capita.

These data were taken and compiled by Mr. Charles Brossman, of Indianapolis; they give a fair idea of the use of water by the towns and cities over the State; and if the statement made by Mr. Clapp, that for the ordinary city forty gallons per capita per day is sufficient, is true, they show that there is a great amount of water wasted every day that might as well be left in the ground. This loss or misuse of water could be remedied by the installation of a sufficient number of meters. Of the 144 towns and cities in

Indiana studied by Brossman, only fourteen had more than 300 meters, 13 between 100 and 300, 51 below 100 meters, and 66 were without meters at all. Thus less than ten per cent of the cities studied had sufficient meters to regulate the amount of water used. In Bloomington, where the municipal water supply is limited, there are very few meters.

The lowering of the water table at Chicago is due to over-development, and cannot be remedied. In 1864, the water in the flowing wells stood 111 feet above the level of Lake Michigan, but at the present time it is fifteen or twenty feet below the ground.

The fourth and last factor concerned in the lowering of the water table is deforestation. This factor has been dealt with to a certain extent earlier in the report but it is well to emphasize the results of deforestation by citing an illustration taken from the 'Eighteenth Annual Report of the United States Geological Survey,' Part Four:

> 'Queens creek of Arizona is a typical stream in a barren treeless water shed which has a rain fall of about fifteen inches per year. The area of this water shed is about 143 square miles and 61 per cent of it is above 3,000 feet. The maximum flood discharge in 1896, was 9,000 cubic feet per second. During a greater portion of the time the creek was dry. In this case there was very little chance for the water to soak into the ground. . . . .
>
> 'Cedar creek, in Washington, is typical of streams flowing from timbered water sheds. The basin of Cedar creek lies on the western slope of the Cascade mountains, and is covered with a dense forest and a very heavy undergrowth of ferns and mosses. The drainage is the same as that of Queens creek, 143 square miles. The precipitation for the year 1897, was 93 inches for the lower portion of the basin and probably 150 inches for the mountain summits; in spite of the fact that the precipitation in Cedar Creek basin was from six to nine times more than that in Queens creek basin, the maximum flood discharge of Cedar creek for 1897, was but 3,601 cubic feet per second, as against the 9,000 cubic feet for Queens creek. On the other hand the flow of Cedar creek was continuous through the year, and the minimum discharge was never less than 27 per cent of the mean for the year. The mean discharge of Cedar creek was 1,089 cubic feet, as against 15 cubic feet for Queens creek. This radical difference between the behavior of the two streams can be explained only by the difference in the soil covering of the two basins. Cedar creek basin is covered with a heavy forest, while Queens creek is almost entirely bare with a few scattered pinyon trees and a little brash or grass.

This illustration shows the intimate relation that exists between the process of deforestation and the control of our flood waters. It also shows an evident cause of the lowering of the water table in this and other states. This is a practical demonstration and should carry considerable weight in the determination of our attitude toward the question of flood control.

Control of Floods in China, Japan, and Korea

The following discussion is based upon F. H. King's 'Farmers of Forty Centuries.'

The people of China, Japan, and Korea are farming land that has been in service almost 4,000 years and there are only two acres per capita, half of which is unfarmable. The question of sufficient room for the masses of the people has been a serious proposition for over 4,000 years. Over 4,100 years ago, Emperor Yao appointed 'The Great Yu,' 'Superintendent of Works,' and entrusted him with the work of draining off the waters of the disastrous floods and of canalizing the rivers. He worked at this for thirteen years, after which he was called to be Emperor. This man saw the need of some definite line of procedure for the conservation of the vast amount of sediment that was yearly being lost by the great rivers, Howang Ho, Yangste Kiang, and the Canton. He realized that the flood waters should be shut off from the precious farm land. As a result this man started a system of canals to be filled with the flood waters, which form today a network of water ways, all over the delta region. A conservative estimate would place the number of miles of canals and leveed rivers in China, Japan and Korea at 200,000 in all. That is, forty canals across the United States from east to west, and sixty from north to south would not equal in number of miles those of the three countries today. King goes on to say that this estimate is possibly not too large for China alone.

These canals are about eight feet below the level of the surrounding fields and are about twenty feet in width. In times of high water these canals are permitted to fill up and when the water in the main stream goes down the water is drawn from the canals. While the water stands in the canals the sediment is deposited in the bottom and after the canals are drained this sediment is carried by hand and spread over the surrounding fields. This not only enriches the fields but builds them up a little higher each time, getting them a little farther from the danger of following floods. As much as an inch of this mud is spread over the fields at a time. This transfer of mud is done by human labor altogether.

To quote from King's, 'Farmers of Forty Centuries,' concerning other processes in conjunction with the canals: 'As adjuncts to these vast canalization works there have been enormous amounts of embankment, dike and levee construction. . . . Along the banks of the Yangtse, and for many miles along the Hoang Ho, great levees have been built, sometimes in reinforcing series of two or three at different distances back from the channel where the stream bed is above the adjacent country, in order to prevent the widespread disaster and to limit the inundated areas in times of unusual floods. Again, in the Canton delta there are hundreds of miles of sea wall and dikes, so that the aggregate mileage of construction work in the Empire can only be measured in the thousands of miles. . . . In addition to the canal and levee construction works there are numerous impounding reservoirs which are brought into requisition to control overflow waters from the great streams. Some of these reservoirs, like the Tungting Lake in Hupeh and Poyang in Hunan, have areas of 2,000 and 1,800 square miles respectively and during the heaviest rainy seasons each may rise through twenty or thirty feet. Then there are other large and smaller lakes in the coastal plains giving an aggregate reservoir area exceeding 13,000 square miles. All of which are brought into service in controlling the flood waters, all of which are steadily being filled with the sediments brought from the far-away uncultivated mountain slopes, and which are ultimately destined to become rich alluvial plains, doubtless to be canalized in the manner that we have seen.'

King also shows how by the process of building up the low swamp land with sediment that is deposited in the reservoirs and in the canals that the land has been pushed out into the sea. By this process, the shore has been pushed seaward from 15 to 50 miles since the beginning of the Christian era.

He sums up the effect of these processes that we have been considering in the following words; 'Besides these actual extensions of the shore lines the centuries of flooding of the lakes and low lying lands has so filled many depressions as to convert large areas of swamp into cultivated fields. Not only this, but the spreading of the canal mud broadcast over the encircling fields has had two very important effects namely, raising the level of the low lying fields, giving them better drainage and so better physical conditions, and adding new plant food in the form of virgin soil of the richest type, thus contributing to the maintenance of soil fertility, high maintenance capacity and permanent agriculture through all the centuries.'

In the United States, along the same lines, now that we are considering the development of inland water ways, the subject should be surveyed broadly and much careful study may well be given to the works these old people have developed and found serviceable through so many centuries. The Mississippi River is

annually bearing to the sea nearly 225,000 acre feet of the most fertile sediment, and between levees along a raised river bed through two hundred miles of country subject to inundation. The time is here when there should be undertaken a systematic diversion of a large part of this fertile soil over the swamp areas, building them into well drained, fertile fields provided with water ways to serve for drainage, irrigation, fertilization and transportation. These great areas of swamp land may thus be converted into the most productive rice and sugar plantations to be found anywhere in the world, and the area made capable of maintaining many millions of people as long as the Mississippi endures, bearing its burden of fertile sediment.

This bears a close relation to the flood situation in Indiana, for any solution of the flood conditions here must begin at the mouth of the Mississippi River and then embrace each of the tributaries. It is almost useless to try to protect different places along a stream even as small as White River. Suppose that we make the whole of White River an ideal stream, one that will carry away all of the excess waters rapidly enough to keep the flood plain from being inundated: railroad grades, public road grades, and bridges to be so constructed that the water would be permitted free passage and not impounded in the least: the channel made large enough to carry an amount of water equal to that of the March flood. What would be the result of such an improvement? The result is easily comprehended: the water will be dumped into the Wabash River in such a short time as to cause it to assume flood conditions at once and the damage will be greater than before the improvement of White River. The region of flood damage would be shifted down stream to the Wabash, where the height of the flood would be greatly increased. The people of the White River Valley would have simply put their troubles and losses on the people below.

It seems impracticable to try to provide a channel large enough to carry the amount of water that came down White River last March. Improvements on the channel would help to take care of the ordinary flood. That is the phase that we wish to guard against first, and then try to cope with floods of the proportions of the recent one.

A Brief Consideration of Reservoirs

The effect of natural reservoirs upon the discharge of streams is shown in a striking manner in the Niagara River. The stream flow here is very constant, the maximum being only 35 per cent greater than the minimum discharge. According to Van Hise, the maximum flow of the St. Lawrence River is only 50 per cent greater than the minimum flow. Considering the size of these rivers, that is a remarkable record. The Kankakee River, which is fed by numerous lakes and swamps, has a rather constant flow, but this equilibrium is being wrought out of adjustment by the draining of a large portion of the swamp land during the last few years. The effectiveness of reservoirs and lakes in making the flow or discharge of a stream constant cannot be overestimated.

Where the relief and geologic structure permit, artificial reservoirs may be constructed in such a way as to hold back a large percentage of the excess rainfall. Much of the unglaciated part of the State is of such a nature. The surplus may be used for irrigation and the production of power in small plants. The power that is developed may be used to lift a part of the water up to the level of the fields that are to be irrigated. The needs and benefits of irrigation in a humid region are being realized today.

Mr. W. W. Roebuck, of Ft. Wayne, Indiana, at the National Irrigation Congress at Chicago, December 5-9, 1911, said, 'I know of an irrigated farm of eighty acres, and there is not more than half of this farm, or there is less than half of this farm that has been cultivated annually, and the products have been over $15,000 annually. It is a demonstrated fact that we can grow more than double, take it one year for another, by irrigation.'

There is sufficient rainfall in Indiana. However, it does not always come at the time needed to produce maximum crops. Three weeks without a rain will often damage a crop fifty per cent, while water applied at the proper time would insure a maximum yield. If it were possible to hold back the surplus waters in times of excessive rainfall, in reservoirs, it could be made to serve a two-fold purpose: it would furnish water for irrigation and at the same time keep the flood stages lower.

In Monroe County there are several places where dams may be constructed where the water may be used either for municipal water supply or for irrigation. Bloomington may secure an ample supply of water by putting a dam across Griffy Creek, just above the North Pike bridge. The excess water of seven square miles may in this way be made useful instead of a menace to life and property, since it, as a contributing factor, causes White River to assume flood stages. Below this dam would be several hundred acres of land that could be made to produce in an unfailing manner. The lack of topographic maps makes it difficult to construct such

reservoirs economically. Properly planned, such reservoirs would pay for themselves by furnishing water for irrigation and at the same time help to reduce the flood stages, and keep the water table from getting any lower.

It is conceded that no system of reservoirs would have been ample to have prevented the recent flood, or even to have mitigated it perceptibly. The truth of this statement is clearly brought out when one considers the enormous amount of water which fell. The following figures will make this clear; they concern the White River basin alone. The water which fell would cover:

7,626	square miles of territory	1 foot deep.
763	square miles of territory	10 feet deep.
305	square miles of territory	25 feet deep.
152½	square miles of territory	50 feet deep.
76¼	square miles of territory	100 feet deep.

Or, from another point of view,—

4,860,640	acres	1 foot deep.
487,064	acres	10 feet deep.
194,826	acres	25 feet deep.
97,418	acres	50 feet deep.
48,706	acres	100 feet deep.

Or, from another point of view,—

10 acres to every square mile 44 feet deep.
20 acres to every square mile 22 feet deep.
40 acres to every square mile 11 feet deep.

Or, from another point of view,—

11 acres to every 160 acres 10 feet deep.
5½ acres to every 80 acres 10 feet deep.

Or, from still another point of view,—

1/15 of any area 10 feet deep.

These figures, based on U. S. Weather Bulletins, show that a system of reservoirs would have had to have been very elaborate indeed to have had any influence upon such a flood as the recent one. It seems to the writers that any reservoir system proposed for the White River region for the mitigation of damage due to floods alone, when the enormous cost is considered, is impracticable. As a side issue only, artificial reservoirs may be thought of in connection with floods in this region.

If we eliminate the reservoir idea, the question of protection

to our cities and towns is still before us. The writers are scarcely willing to venture any proposal, not having given this phase of floods more than passing notice. But it seems that the one practical thing for the present is to build strong levees sufficiently high to prevent the possibility of the waters getting over them into the towns and cities. A study of the situation will very likely prove this proposition not only practical, but a necessity, if any precautions are to be taken at all.

PART IV. SUMMARY OF FACTS AND CONCLUSIONS

1. Excessive rainfall was the only cause of the flood.

2. The excessive rainfall was due to two areas of high pressure, one over the Bermuda Islands and the other over Eastern Canada, remaining stationary from March 22nd to March 27th, holding back the two storms, causing them to spend their energy over the Ohio Valley for five days.

3. There was an average of 10.53 inches of rainfall at twenty weather bureau stations, in the White River drainage basin.

4. Only 2.43 inches of rain fell during the first twenty-two days of March.

5. An average of 8.28 inches of rain fell between March 22-28.

6. Within twenty-four hours 56.6 per cent. of the precipitation fell that caused the flood, or an average of 4.46 inches for the entire drainage basin.

7. Floods in the Ohio Valley are generally caused by heavy rainfall, melting of heavy snow, ice jams, failure of reservoirs, and the breaking of levees. The latter four factors generally act in conjunction with the excessive rainfall.

8. According to Leighton, floods in the Eastern part of the United States are increasing, and that the main cause for the increase is deforestation. However, in the White River valley, the writers think that the enormous increase of artificial drainage should be added to deforestation.

9. The water table of large parts of the State is being lowered by the increase of artificial drainage, deforestation, the waste of water by cities, and the general waste of water, as at abandoned oil wells.

10. Many lakes in the northern part of the State could be equipped with flood gates at their outlets, thus holding back much of the excess rainfall, permitting it to be carried away after the crest of the flood has passed. This would partly restore the water table. This would be practical for the upper Wabash region.

11. If meters were installed to regulate the amount of water used in cities the waste would be reduced almost one-half.

12. Mr. Charles Brossman has shown that only 10 per cent of the cities of Indiana have a sufficient number of meters to regulate the amount of water used.

13. A close study of Cedar Creek in the State of Washington, and Queens Creek in the State of Arizona, shows that deforestation increases the immediate run-off, makes the flood stages higher, and the low water stages lower.

14. Deforestation causes an increase of soil erosion.

15. Natural reservoirs on large streams tend to make the flow constant.

16. Where relief and geologic structure permit, artificial reservoirs may be constructed, holding back part of the flood waters which may be used for municipal supply, power and local irrigation.

17. It is a demonstrated fact that irrigation in a humid climate will greatly increase the crops and guard against drouth.

18. Along much of its course White River flows two miles to get one. In many places a two-mile stretch of river could be reduced to less than a mile by making a cut-off.

19. In many cases a series of dynamite charges could be used to open up the new channel instead of the expensive method of dredging.

20. Shortening the course increases the fall, which will be distributed up and down the channel.

21. By doubling the velocity, the transporting power is increased sixty-four times.

22. As soon as the water spreads out over the banks it takes a more direct course, thus having its velocity increased. However, the friction is greater and tends to check the current.

23. A meander increases in size up to a certain stage and then the current which has been cutting on either side of the neck meets and a cut-off is perfected.

24. A cut-off generally throws the current to the opposite side of the stream, thus starting a new meander.

25. Stumps, trees, hay stacks, posts, and buildings on the flood plain may cause the current to cut holes.

26. Under the top soil which is from one to ten feet in depth is a layer of sand and gravel, which is easily moved by running water, causing the top soil to cave or fall in.

27. This gravel and sand shows that the stream has been shifting back and forth across the valley for a long time.

28. These beds of sand and gravel were formerly sand and gravel bars and in many cases show the structure.

29. Sand and gravel were deposited in areas up to 80 or 100 acres, and from a few inches up to ten feet in depth.

30. As a rule this sand was deposited upon good farming land.

31. Silt was deposited at the junction of the two forks in greater quantities than elsewhere. The next largest area of silt

deposition was at the mouth of the Muscatatuck, on the East Fork.

32. On the West Fork the loss from bank cutting must be as much as 100 acres per year and may be three or four times that amount, but not less.

33. There was at least 7,850 acres denuded, 160 acres lost by bank cutting, 1,520 acres badly covered with sand and gravel, and 15,600 acres covered with silt.

34. By using the statements of possibly a hundred farmers as to how much each of these different factors damaged the land, the estimate damage to soil alone was placed at $246,500. The total cost of replacing the structure damaged and destroyed is estimated at $498,998.

35. When the upper portion of the drainage basin has been deforested, the sediment that is derived from it and deposited on the flood plain is not so productive as it was before the removal of the forest.

36. China uses the sediment of her great rivers to build up the low ground near the delta region, thus reclaiming many hundreds of square miles for agriculture.

37. A great amount of the flood water is diverted by a system of canals into the low lying land where much sediment is deposited in the bottom of the canals and is later carried out upon the nearby fields, both enriching and building them up above the danger point of future floods.

38. Considerable bottom land of the lower Mississippi River could be reclaimed in this manner.

39. Railroad bridges are generally too small and restrict the flow of water.

40. The railroads that crossed the valley on trestle-work were not damaged.

41. Where a bridge or part of a railroad grade was washed out the railroad companies have not increased the length of trestle-work, but have rebuilt the grade.

42. Bank cutting is not limited to times of excessive floods, and can be prevented by the planting of trees, riprap, and jetties.

43. In the stretch of river studied the greatest loss was due to soil wash.

44. There has been no attempt to conserve the great amount of sediment that is being carried to the ocean.

45. The flood occurred at a time of year when there was a minimum amount of damage to the growing crops.

46. The flood of August, 1875, did more damage to the growing crops.

47. The flood of 1875 and the recent March flood were about the same in height.

48. The Mississippi River has been brought under control to a large extent by a system of levees.

49. No practical system of levees could have held White River within its banks.

50. At Romona, where the bluffs act as levees, the water was twenty to thirty feet in depth over the flood plain.

51. Groundhogs are the chief enemies of the levees on White River.

52. The valley is wide where it passes through the region of shales and is narrow in the limestone region.

53. Where the valley is wide the water spread out and killed much wheat. Where it is narrow, much damage was done by the erosive power of the currents.

54. As a rule, in the parts of the cities that were flooded there was less disease than at any corresponding time before. They cleaned up.